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INVESTIGATION OF DC-8 NACELLE MODIFICATIONS TO REDUCE FAN-COMPRESSOR NOISE IN AIRPORT COMMUNITIES

Part IV - Flight Acoustical and Performance Evaluations

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16. Abstract

Acoustically-treated engine nacelles for Douglas DC-8-50/61 airplanes were flight tested using a DC-8-55 airplane. The flight noise and performance measurements were supplemented by measurements made on an engine test stand. Significant noise reductions were obtained with the nacelle modifications. Beneath the landing approach path, at a height of 370 ft and with a landing weight of 240 000 lb, the effective perceived noise level would be reduced by 10.5 EPNdB. Beneath the initial-climb flight path, a 325 000-lb airplane climbing with rated-takeoff thrust would produce 3.5 EPNdB less noise at a point 3.5 n. mi. from start of takeoff roll and 3 EPNdB less maximum noise along a 1500-ft sideline. Installed net thrust at rated-takeoff power was reduced 2.1 percent with the nacelle modifications. Cruise performance was improved with an average 3-percent increase in specific range. No adverse engine operational characteristics were encountered.

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CONTENTS

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SUMMARY

In May 1967, a program was initiated to investigate turbofan engine nacelle modifications designed to reduce fan-compressor noise from the JT3D engines on DC-8-50/61 aircraft. The program was directed at the definition of nacelle modifications that could reduce the landing-approach flyover perceived-noise level by 7 to 10 PNdB with no increase in takeoff noise. The program was conducted in five phases: (1) nacelle design studies and duct-lining investigations, (2) ground static tests of noise suppressor configurations, (3) flyover-noise tests and cruise-performance tests, (4) studies of the economic implications of retrofit, and (5) an evaluation of human responses to the flyover noise of the modified nacelles. This document reports the results of the third phase of the program. The test-nacelle modifications consisted of acoustically treated inlet and fan-exhaust ducts. The acoustical treatment was a single-layer duct-lining design with porous fibermetal bonded to fiberglass honeycomb.

Tests of both the existing and flight-test modified nacelles were conducted on an outdoor static engine test stand prior to the flight tests. Data from these tests were used to evaluate the effects of the nacelle modification on far-field noise, rated engine thrust, engine surge susceptibility in simulated crosswinds up to 35 knots, and fan disk and blade stresses. The results of the tests showed that the effects on far-field noise were similar to those measured previously with static-test nacelles. The nacelle modification resulted in a 2.5 percent reduction in thrust at takeoff-rated power. The drag caused by the fan-exhaust flow scrubbing the external surface of the nacelle was reduced by 0.4 percent. The reduction in installed net thrust at takeoff-rated power was therefore 2.1 percent. No engine surges were experienced throughout the tests.

Flyover noise tests were conducted with a DC-8-55 airplane using first the existing and then the modified nacelles. Acoustical analyses in terms of effective perceived noise levels (EPNL) indicated that the nacelle modification resulted in significant noise reductions. At a distance of 370 feet under a 3-degree landing flight path, the modified nacelles would reduce the EPNL by approximately 10.5 EPNdB for an airplane at a 240 000-lb landing weight. At 3.5 n. mi. from brake release, the modified nacelles would reduce the noise below the initial-climb flight path by approximately 3.5 EPNdB for airplanes with a takeoff gross weight of 325 000 lb and climbing with V_2 + 10 kn airspeed and takeoff-rated thrust. The maximum EPNL along a line 1500 ft to the side of the takeoff flight path would be reduced approximately 3 EPNdB with the modified nacelles on a 325 000-lb airplane.

Reducing the thrust, from takeoff-rated thrust to that required for a 6-percent climb gradient with the 325 000-lb airplane, would reduce the EPNL of the modified airplane at the 3.5-n. mi. point by approximately 5.5 EPNdB.

Aircraft performance and operational tests were conducted with the airplane in both the existing and the modified configurations. The modified nacelle resulted in an average specific-range improvement of 3 percent at typical cruise conditions. Engine and airplane operations were evaluated during normal flight conditions;no adverse or abnormal operational characteristics were encountered.

INTRODUCTION

The growth of the air transportation industry and the increase in the number of people living in communities around airports have increased human annoyance due to operations of commercial jet transports. This increased annoyance has stimulated efforts to find means to alleviate the problem through reducing the level of the noise radiated from airplanes, modifying airplane operational procedures, and achieving compatible usage of the land around airports. These efforts are being conducted as part of a coordinated industry-government research program.

In 1965, the NASA extended its research programs to supplement those of industry in the development of practical nacelle modification concepts for reducing noise. In May 1967, the Langley Research Center of the NASA contracted with the McDonnell Douglas Corporation and The Boeing Company to investigate nacelle modifications for operational Douglas and Boeing transports powered by Pratt & Whitney Aircraft (P&WA) JT3D turbofan engines. The nacelle modifications were to achieve significant reductions in flyover noise levels in airport communities located under landing-approach flight paths.

During landing approach, the perceived noise, and hence the annoyance of the sound, from the JT3D engines is attributed principally to the discrete frequency tones radiated from the fan stages through the inlet and fan-exhaust ducts. Accordingly, the McDonnell Douglas and Boeing investigations were directed at developing fan-noise suppression methods. The goal of the McDonnell Douglas program was to design, build, and evaluate an economically viable nacelle modification primarily through the use of acoustically treated short fan-exhaust ducts and acoustically treated inlet ducts. A secondary concept to be investigated consisted of reducing the fan rotational speed for a given landing thrust by controlling the exhaust area of the primary nozzle. These modifications were to achieve a reduction of 7 to 10 PNdB in perceived noise level (PNL) outdoors under the landing approach path, and was to produce no increase in noise during takeoff or climbout.

The noise reduction goals were stated in terms of PNL because that measure of human annoyance due to noise was in wide use at program initiation. As the program proceeded, increasing interest developed in assessing the noise reduction in terms of effective perceived noise level (EPNL). This measure includes allowances for the annoyance due to pure tones in the noise spectra and due to the duration of the noise. The flight test program was therefore planned to obtain the data needed to permit assessment of the noise reductions in terms of EPNL.

The scope of the McDonnell Douglas investigation was limited to the study of nacelle modifications for the various models of the Series 50 DC-8 airplanes and for the Model 61 of the Series 60 airplanes. These airplanes are equipped with 24-inch-long fan-exhaust ducts, referred to as short ducts.

The Boeing program is summarized in reference 1. The McDonnell Douglas program is reported in six parts: Part I, a summary of the major results of the program (ref. 2); Part II, a report of the initial nacelle modification design studies and duct-lining investigations (ref. 3); Part III, a report of static tests of noise suppressor configurations (ref. 4); Part IV, a flight evaluation of the acoustical and performance effects of the selected design of modified nacelles on a DC-8-55 airplane (presented in this document); Part V, a study of the economic implications of retrofitting the selected design (ref. 5); and Part VI, an evaluation of human response to the flyover noise of the modified nacelles (ref. 6).

Prior to the design of the test nacelle parts, a preliminary design of the selected modification was generated to a depth sufficient to assure compatibility with a production retrofit program. The test nacelle parts were designed to incorporate the features needed to permit an adequate evaluation of the acoustic, aerodynamic, and engine performance and operational effects of the modification. In the interests of program economy, certain features needed in production nacelles were not included, e.g., fan thrust reversers, operable anti-icing systems, and access doors suitable for routine service.

The flight-test nacelle was first tested during ground static operation in order to verify the characteristics originally defined by the static-test modified nacelle described in reference 4. The purpose of the flight tests was to obtain the data needed to evaluate the acoustical and performance effects of the modified nacelles. In addition, engine and airplane operational characteristics affected by the modification were to be evaluated in a qualitative manner. The flight evaluation was to consider the performance effects of the nacelle modifications as installed retroactively on the Model DC-8-55 airplane.

Changes in acoustical, aerodynamic performance, and operational characteristics were determined by testing and comparing the results of both the existing and modified nacelles. Determination of the change in flyover noise required measurement of the effects of engine thrust setting, airplane airspeed, and distance upon sound pressure levels throughout the flyovers. Sufficient similarity existed between the designs of the existing and modified nacelles to require flight determination of performance for only the level-flight cruise condition. Other aspects of the modified-nacelle flight performance were calculated on the basis of data obtained in the static-tests.

This report describes the overall evaluation of the modified nacelles. Five major topics are included:

1. The design and construction of the modified nacelles as well as relevant characteristics of the test airplane.

2. Nacelle evaluations using static test-stand facilities.

3. Flight tests to determine basic flyover-noise data.

4. Flight tests to determine cruise performance and to evaluate engine and airplane operational characteristics.

5. Calculated changes in flyover noise levels, flight performance, and operational characteristics of airplanes retrofitted with the modified nacelles.

The materials and manufacturing processes used for fabricating the acoustical duct linings were dictated by the technology available in 1967. Concurrent development work since that time has shown that materials for a production retrofit program may be chosen from a wider variety of possibilities than was apparent in 1967. A choice of materials different from those studied in this program would imply differences in manufacturing methods, maintenance methods, and durability; but such a choice would not be expected to result in important differences in acoustical or aerodynamic characteristics.

SYMBOLS

D	duration correction factor, dB
EPNL	effective perceived noise level, effective perceived noise decibels (EPNdB)
EPR	indicated engine pressure ratio, p_{t_7}/p_{t_0}
F_g	gross thrust, pounds
F_n	installed net thrust, pounds
MHB	maximum half breadth, inches
N_1	low-pressure compressor-rotor shaft speed, revolutions per minute
N_2	high-pressure compressor-rotor shaft speed, revolutions per minute
PNL	instantaneous perceived noise level, perceived noise decibels (PNdB)
PNLM	maximum value of the instantaneous PNL, PNdB
PNLT	instantaneous tone-corrected PNL, PNdB
PNLTM	maximum value of the instantaneous PNLT, PNdB
p_{am}	ambient pressure, pounds/square foot
$p_{am\ sl}$	ambient pressure at sea level, 2116 pounds/square foot
p_{local}	local static pressure, pounds/square foot
p_{t_0}	total air pressure of free stream, pounds/square foot
p_{t_7}	total pressure at inlet to primary exhaust duct, pounds/square foot
q_i	dynamic pressure at inlet throat, pounds/square foot
SFC	specific fuel consumption, (pounds/hour)/pound
SPL	sound pressure level, decibels (dB) re 0.0002 dynes/square centimeter

$T_{am\ std}$	standard-day ambient air temperature, 518.7° Rankine
T_{t_2}	total air temperature at engine inlet, degrees Rankine
V_2	FAA takeoff safety speed, knots
W	airplane gross weight, pounds
w_f	fuel flow, pounds/hour
δ_{am}	ratio of ambient pressure to 2116 pounds/square foot, $p_{am}/p_{am\ sl}$
θ_{t_2}	ratio of total air temperature at engine inlet to 518.7° Rankine, $T_{t_2}/T_{am\ std}$

DESCRIPTION OF NACELLES AND TEST AIRPLANE

Modified Nacelle Design for Retrofit

Based on the results of the static tests reported in reference 4, it was determined that the combination of a "one-ring inlet" (i.e., a two-ring inlet with the inner ring removed) and 48-inch-long fan-exhaust ducts would constitute a suitable design concept for flight evaluation and possible retrofit to existing DC-8 installations of short-duct JT3D nacelles. This section of the report describes the design of a production retrofit nacelle modification, which formed the basis of the design of the flight-test nacelle parts.

General design features. – Plan views of the existing nacelle and the retrofit version of the modified nacelle are shown in figure 1. The modified nacelle differs from the existing nacelle in four major respects:

1. New inlet with concentric ring-vane and new centerbody

2. New fan exhaust ducts

3. Revised nacelle subsystems

4. New fan thrust reversers

The design provides a total area of approximately 64 square feet of acoustical treatment on the inlet duct inner surface, the centerbody, and the inner and outer surfaces of the concentric ring. The overall inlet length of 45 inches is unchanged from the untreated, existing inlet. The concentric ring is supported by eight untreated support struts, four located near the ring leading edge and four near the ring trailing edge. These airfoil-shaped struts are located on the vertical and horizontal centerlines of the inlet. This arrangement of the support struts is different from that of the inlet tested in reference 4. The design was changed to reduce the possibility of the support strut wakes exciting fan-blade vibrations. The inlet duct utilizes the existing inlet lip and auxiliary air intake, but refairing of the external loft lines of the cowl was necessary to accommodate the new exhaust duct lines. The modified inlet also duplicates the existing inlet by incorporating the 4-degree downward cant of the inlet plane necessary to correct for wing upwash, nacelle attitude, and cruise angle of attack.

The 48-inch fan-exhaust ducts provide approximately 70 square feet of area for acoustical treatment on the interior walls and both sides of the flow splitters. These longer ducts require modifications to the engine power controls, engine and nacelle pneumatic ducting, hydraulic system piping, engine-surge bleed ducting, and engine overboard drains.

Aerodynamic design. – The shapes of the modified inlet duct, concentric ring, and centerbody were developed with the aid of potential flow calculations. These calculations were performed in a simplified and conservative manner: pressure distributions were determined for separate axisymmetric bodies, each shaped according to selected loft lines of the modified (non-axisymmetrical) inlet duct. The pressure coefficients are shown in figure 2, which depicts the pressure distributions along the surfaces of the inlet duct and the centerbody for the top, bottom, and maximum-half-breadth (MHB) circumferential locations. (The MHB point, at any axial station, is located at the maximum projected width in a plan view.) The pressure distributions along the surfaces of the concentric ring are depicted separately in figure 3. This figure demonstrates that the ring is subjected to hoop tension. The pressure coefficients of figures 2 and 3 were used in a boundary layer analysis; this analysis indicated that flow separation would not occur during aircraft operations.

Pressure distributions required for satisfactory inlet airflow characteristics, and pressure differentials required for structural stability were achieved. The cowl lip did not affect the pressure distribution aft of nacelle station 70, leaving only the ring leading-edge pressures affected by the inlet camber. The differential pressure across the concentric ring indicated that hoop tension would still be present, except at the bottom leading edge of the ring. The difference between top and bottom differential pressures indicated a net lifting force on the ring leading edge.

The internal aerodynamic design of the fan-exhaust ducts was developed to conform to a satisfactory distribution of cross-sectional duct area, as detailed in reference 4. Externally, the nacelle contour was smoothly faired from the maximum cross-section to the fan-exhaust-duct exit plane, resulting in a boattail angle of approximately 9.5 degrees, thus satisfying a requirement of less than 10 degrees for acceptable drag characteristics. These modifications did not alter the maximum cross sectional area or the overall length of the nacelle.

Retrofit nacelle subsystems. – Several changes were necessary to accommodate the acoustical treatment and to assure the reliability and maintainability essential to commercial airplanes. Inlet cowl subsystems of retrofitted modified nacelles would be similar to those of airplanes presently in service but would require modifications to prevent physical interference with the acoustical treatment.

The inlet cowl changes principally involved anti-icing. The cowl ice-protection system would require modification to provide ice protection for the concentric ring and its supporting struts. Anti-icing of these members would be accomplished by engine bleed air. Sufficient heated air would be provided to the leading edge of the concentric ring and struts to obviate the need for ice protection for the acoustical treatment itself. Ice buildup during the most critical icing conditions would not be permitted to exceed a triangular shape 0.15-inch high by 6 inches long. This anti-icing concept, illustrated schematically in figure 4, would provide engine bleed air to the cowl lip and centerbody as in existing systems. Additional engine bleed air would be ducted into the leading edge of the concentric ring through ducts in the two vertical struts, passing through one-half of the leading-edge circumference and exiting through the two horizontal struts to an overboard exhaust. This concept would avoid mixing the anti-icing air with inlet airflow and the resultant inlet performance degradation.

In the retrofit configuration, access to the engine gearbox and accessories would be provided by an intermediate joint in the fan-exhaust ducts. The forward section of the duct would be removable in the same manner as the existing ducts, while the aft section would be hinged in a manner similar to the engine access doors. The access doors would be of either skin-and-stringer or honeycomb construction, and would be provided with quick-access latches.

Space downstream from the fan nozzles dictated a "target" design concept for the fan thrust reverser. This concept involves a hydraulically actuated single-panel deflector mounted on each side of the nacelle. Although the overall weight of the modified nacelle was reduced by this type of reverser, the overall thrust-reverser effectiveness may also be reduced during ground operation. However, predicted overall effectiveness is comparable to that of other target-type reversers on airplanes presently in airline service.

The changes required to retrofit an acoustically treated nacelle to DC-8-50/61 airplanes are summarized in table I.

Retrofit materials and construction. – The duct-lining design selected for the retrofit configuration consisted of a sandwich construction with an impervious backing, a honeycomb core, and a porous facing sheet. The specific materials for the design are listed in table II. The sandwich construction would be assembled by bonding the component parts with a film epoxy-resin adhesive.

To prevent liquid entrapment in the honeycomb cell structure of the acoustical treatment in the inlet and fan-exhaust ducts, drainage passages would be provided for all cells whose orientation prevents drainage through their porous facings. The drainage passages would consist of 1/8-inch by 1/4-inch slots, located at the bottom of each cell (adjacent to the impervious backing) and midway between cell nodes in adjacent cell rows. This orientation of drainage passages would result in interconnected cells in rows transverse to the direction of airflow, thereby reducing the air circulation through the linings due to duct longitudinal pressure gradients. Liquids would be led to a drain manifold and ducted overboard.

The total weight increase, including all new parts and all subsystems changes, was estimated at 83 pounds per nacelle, or 332 pounds per airplane. Estimated weight changes for the nacelle components are included in table III. Other components requiring change are estimated to weigh the same as the corresponding existing components.

Modified Nacelle Design for the Flight-Test Configuration

The modified nacelles constructed for the flight evaluation were designed to duplicate the aerodynamic and acoustical characteristics of the retrofit configuration. The prominent features of the modified nacelle inlet and fan-exhaust duct for flight testing are shown in figure 5.

Aerodynamic design. – The aerodynamic design of the flight-test configuration of the modified nacelle inlet was the same as that of the retrofit configuration.

Test-nacelle subsystems. - In addition to the modifications necessitated by the increased length of the fan-exhaust ducts and in the interest of simplicity, the flight-test modified nacelles excluded some nacelle subsystems. The pneumatic-system heat exchanger, required when using engine high-pressure bleed air, was eliminated because satisfactory performance could be obtained for a flight test program with only the engine low-pressure air-bleed subsystem. The blowaway jet and oil cooler jet pump were not required, and were therefore omitted. However, the accessory-compartment ground-cooling ejector was retained to preclude the necessity for limiting engine power during ground operations. Consistent with these installations, the engine high-pressure bleed line was capped near the existing pressure regulator. Because the modifications did not permit engine starting by cross-bleeding from the airplane pneumatic system, each engine was started from a ground connection. The air-cooled engine-oil heat exchanger was replaced by a fuel-cooled engine-oil heat exchanger.

The auxiliary air inlet, which normally provides cooling air for the pneumatic and engine-oil heat exchangers, was retained, but was physically blocked to prevent airflow into the cowl. This condition approximates cruise flight conditions during which little external airflow is ducted to these subsystems. Because no combustible fluids were to be present in the modified inlet, the inlet ventilation ducting was omitted. An existing generator cooling inlet was retained in the modified inlet structure to provide ram-air cooling to the generator.

Two major nacelle subsystems were omitted from the flight-test configuration of the modified nacelles, the inlet ice-protection unit and the fan-exhaust reversers. The size and shape of the inlet-ring support struts reflected the requirement for bleed air ducting in each strut to provide adequate ice protection for both the ring and its support struts. However, no operative inlet ice-protection system was provided. Space provisions for the target fan-thrust reversers were made in the flight test nacelles. The primary-exhaust thrust reverser and its fairing, as well as the primary exhaust nozzle and its fairing were unchanged.

Materials and construction. – The materials used throughout the modified nacelles constructed for the flight evaluation were the same as described earlier for the retrofit configuration, except that the inlet centerbody and the fan exhaust duct walls both utilized fiberglass laminate for the impervious backing sheet rather than aluminum and titanium as listed in table II. The honeycomb cell structure was provided with drainage passages, as described previously. An existing steel engine-attach ring was adapted to support the inlet duct at the engine-attach flange. The concentric-ring support struts were fabricated from aluminum alloy bars, incorporating two steel tie rods in each strut to carry structural loads. The inlet centerbody was supported by a steel cone bolted directly to the engine centerbody support flange. For economy, the conventional access doors were replaced with aluminum alloy panels, which were 0.125-inch thick and held closed by flush screws and floating anchor nuts at the lower centerline joint. The features of the test configuration are illustrated in figure 6.

The uniformity of the flow resistance, a measure of porosity, of each sheet of fibermetal was checked before it was released for use in fabricating the acoustically modified ducts. These checks ensured that the sheets met the uniformity requirements described in Appendix A of reference 3. The results indicated that the mean flow resistance of all of the sheets was acceptably close to the desired value.

Installation techniques. – A short-duct nacelle assembly of a production JT3D-3B engine was used as a mockup for designing and fitting modified nacelle components. Figure 7 shows the mockup with some of the revised subsystems installed. Four complete sets of nacelles were fabricated and fit-checked using this procedure. A test nacelle, as completely installed for flight, is pictured in figure 8.

Test Airplane Characteristics

The airplane selected for the flight evaluation was a Douglas Model DC-8-55, powered by four P&WA JT3D-3B short-duct turbofan engines. The test airplane was a freighter capable of either all passenger or all cargo operations, or a combination of passenger and cargo operation.

The only differences between the flight test airplane with the existing nacelles and a production version of the same model consisted of the addition of the flight test instrumentation, ballast provisions, and flight test emergency equipment.

Airframe. – The flight test airplane was leased from Seaboard World Airlines. The airplane is pictured in figure 9 and had the characteristics listed below.

Body length	146.3 ft
Wing span	142.4 ft
Wing sweepback	30.6 deg
Horizontal tail span	47.5 ft
Maximum ramp gross weight	328 000 lb
Maximum takeoff gross weight	325 000 lb
Maximum landing gross weight	240 000 lb
Maximum zero fuel weight	224 000 lb
Operator's weight empty*	137 490 lb

*Configured for commercial international passenger operation with 135 passengers.

Engine and existing nacelle. – The sea-level static thrust ratings of the JT3D-3B engine are listed below:

Takeoff thrust, flat rated to 84°F	18 000 lb/engine
Maximum continuous thrust	16 400 lb/engine
Maximum cruise thrust	14 800 lb/engine

The JT3D-3B engines had the standard arrangement of 35 first-stage rotor blades and 32 second-stage rotor blades. The existing short-duct nacelles utilized for the flight tests were the same as those fitted on all DC-8-50/61 airplanes. No changes were made in the existing nacelle configuration for the flight tests, other than the installation of test instrumentation. The subsystems of the existing nacelle were utilized during the tests such that the comparison of test results would not be measurably affected by the nacelle differences due to the subsystem deletions in the modified configuration. For example, during flight operations with the existing nacelle, the engine high-pressure bleed-air subsystem was not used; this procedure was equivalent to the effect of capping the high-pressure bleed line for the flight tests with the modified nacelle. In addition, no changes were made to the components that affect bleed-air leakage in the low-pressure air-bleed subsystem for both nacelle configurations.

Airborne test instrumentation. -- The test airplane was equipped with calibrated instrumentation to measure airplane and engine parameters. Data were recorded with a pilot's instrument panel (cockpit) camera, a test-instrument-panel camera (photo-recorder) and an oscillograph. The photo-recorder and oscillograph are pictured in figure 10. The airborne instrumentation is listed in table IV. In addition to this instrumentation, the airplane VHF radio receiver was equipped with time-correlation devices to correlate airborne and ground recordings.

TEST STAND EVALUATIONS

Test stand evaluations of the modified nacelles built for flight tests were conducted for several purposes at two different facilities. Tests at the McDonnell Douglas engine test stand at Edwards Air Force Base, California were made to verify the far-field acoustical characteristics and engine performance effects of the modified nacelles, and to verify the structural integrity of the treated inlets and fan discharge ducts by installing all four sets on the engine and operating them throughout the complete range of engine power. Tests at a P&WA test stand at East Hartford, Connecticut were made to investigate the effects of the nacelle modification on compressor-surge susceptibility and fan vibrational stresses, and to further investigate the effects of the modification on engine performance.

Far-Field Acoustical Tests

Procedures. – SPL measurements for the flight-test modified nacelle were made around the engine test stand along a 150-ft arc centered at the primary jet exhaust nozzle. Noise measurements were made for only one of the four sets of modified nacelles with the concentric-ring inlet and the 48-inch fan-exhaust ducts. For comparison, SPL measurements were also made of the noise from the existing inlet and fan-exhaust ducts installed on the engine.

The test operations, data acquisition, and data processing were nearly identical to those described in reference 4 for the static noise-suppressor tests. One significant exception was that the acoustical data reduction produced twenty-four 1/3-octave-band SPLs rather than a combination of 1/1 and 1/3-octave-band SPLs.

Results and discussion. – The results of the far-field acoustical tests are discussed in terms of the SPLs measured at 150 ft from the primary jet-exhaust nozzle. The SPLs were the average values from three runs on each test configuration. The effect of the nacelle modification on noise was determined in terms of (1) 1/3-octave-band SPL spectra at 60 and 110 degrees from the engine inlet, and (2) directivity of selected 1/3-octave-band SPLs. The SPLs for the modified nacelle were analyzed for both the flight and the static-test versions to determine if there was any change in acoustical performance over that reported in reference 4.

Spectral and directivity changes are presented for two engine power settings – 4600-rpm referred low-pressure rotor speed, representative of a landing-approach power setting, and 6300-rpm, representative of a takeoff power setting. The tabulated 1/3-octave-band SPLs are provided in Appendix A for the 14 microphone locations and the 9 engine power settings used for the tests of the existing and modified flight nacelles.

SPL spectra: The SPL spectra for the landing and the takeoff power settings are given in figures 11 and 12. As noted in reference 4, there were significant reductions at both power settings in the SPLs at the fundamental and the harmonics of the blade-passage frequencies in the forward and in the aft quadrants. Comparing the SPLs from the flight nacelle to the SPLs from the existing nacelle, at 4600 rpm the fundamental in the 2500-Hz band (figure 11) was reduced by 12 dB at 60 deg and 18 dB at 110 deg. At 6300 rpm, the fundamental in the 3150-Hz band (figure 12) was reduced approximately 7 dB at 60 deg and 10 dB at 110 deg.

Noise levels due to combination tones or multiple-pure tones were also decreased by the modified nacelle. These tones are in the 1000, 1250, and 1600-Hz bands at 4600 rpm and in the 1250, 1600, and 2000-Hz bands at 6300 rpm.

In the frequency region above 1000 Hz, the flight-test modified nacelle produced higher SPLs in almost every 1/3-octave band than the static-test modified nacelle previously tested and described in reference 4. The cause of the higher noise levels, at both azimuths and both power settings, is not known. The static and flight fan-exhaust ducts were built with the same construction methods, had the same type of porous surface material, had the same treated area and cavity depths, and had the same type of 0.25-in.-thick fiberglass laminate for the impervious backing sheet. The static and flight inlet ducts had the same type of porous surface material and the same treated areas and cavity depths.

The differences between the inlet ducts are noted in table V. Except for the addition of drainage grooves in the honeycomb core, the inlet duct differences should not have been the cause of the higher SPLs. The fan-exhaust ducts on the flight-test nacelle also had the drainage grooves in the honeycomb while the fan-ducts on the static-test nacelle did not have the drainage grooves.

In the frequency region below 1000 Hz, both the static and flight modified nacelles produced higher SPLs than the existing nacelle. At the takeoff power setting, figure 12, the SPLs from the static and flight-test nacelles were nearly identical and approximately 2 dB greater than those of the existing nacelle. At the landing power setting, figure 11, the SPLs from the flight-test nacelles were 1 to 2 dB less than those of the static-test nacelles and 1 to 2 dB greater than those of the existing nacelle in the frequency region below 1000 Hz.

The reasons for the increase in the jet-exhaust noise with the modified nacelles, and for the differences in the noise produced by the two modified nacelles, are not known. However, it is suspected that the increase in jet-exhaust noise is due to a change in the shear gradients between the fan-exhaust flow and the primary-exhaust flow caused by extending the fan nozzle 24 inches closer to the primary nozzle.

Directivity: The directivity of the SPLs in the 1/3-octave bands containing the blade-passage frequencies is shown in figures 13 and 14 for the landing and takeoff power settings. The directivity of the 1/3-octave band near the frequency of the maximum jet-exhaust noise (125 Hz for 4600 rpm and 250 Hz for 6300 rpm) is also shown.

At the landing-power setting, the blade-passage-frequency noise, figure 13(a) for the fundamental and figure 13(b) for the second harmonic, was substantially reduced in the aft quadrant (90 to 157 deg) with the modified nacelles. In the forward quadrant, the tone in the 2500-Hz band was still predominant [see spectrum in figure 11(a)] and had a maximum value at an angle of approximately 35 deg. The jet-exhaust noise had a maximum value at an angle of 140 deg for each of the three nacelle configurations.

At the takeoff power setting, the SPLs of the blade-passage tones from the modified nacelles did not have any pronounced directivity, figure 14(a). The jet-exhaust noise still peaked at 140 deg, figure 14(b), but at a level approximately 17 dB higher than noted at the landing power setting at 140 deg, figure 13(c).

Differences in the SPLs produced by the flight-test and static-test versions of the modified nacelle, similar to the differences noted in the spectral comparisons at 60 and 110 deg, were apparent at azimuths from 15 to 157 deg. Although the SPLs at frequencies above 1000 Hz from the flight-test nacelle were higher than from the static-test nacelle, it was estimated that the flight-test nacelles could still meet the design goal and were therefore sutiable for use in the flight-test program.

Nacelle Performance and Operation

Procedures. – McDonnell Douglas tests were conducted using the same methods and instrumentation described in reference 4. All four modified fan-exhaust ducts were tested to adjust their exit areas as required to ensure that the relationship between the low-pressure rotor speed and fan pressure ratio (i.e., the ratio of fan-discharge to fan-inlet total pressure) was the same as that for the existing nacelle. One nacelle set of modified inlet and fan exhaust ducts was subjected to a comprehensive performance evaluation. The performance of the other three nacelle sets was monitored during the structural integrity checks. Since performance measurements were incidental to the structural integrity tests, the wind-speed limit for accurate performance measurements (3 knots) was waived in the interest of schedule considerations.

The P&WA tests involved three different nacelle configurations on a JT3D-3B engine:

1. P&WA bellmouth inlet and existing fan-exhaust ducts
2. Modified inlet and existing fan-exhaust ducts
3. Modified inlet and modified fan-exhaust ducts

Performance data from tests of configurations 1 and 2 above were used in determining the effects of the nacelle modification on engine thrust ratings. Tests of configuration 3 were used to investigate the effects of the nacelle modification on engine surge susceptibility and fan disk and blade stresses. The capability of the P&WA facility to generate artificial 90° cross winds at speeds up to 35 knots was used for the surge susceptibility tests.

Results. – Performance data of the modified nacelle obtained by McDonnell Douglas (under the conditions required for precise measurements) are compared in figures 15(a) and (b) with the results of (1) the McDonnell Douglas tests of the static-test nacelle (ref. 4), (2) the McDonnell Douglas tests of the existing nacelle, and (3) the P&WA tests of the modified inlet duct. Figure 15(a) indicates that the gross thrust of the modified nacelle at a given indicated EPR was within approximately 0.5 percent of that of the existing nacelle. From figure 15(b) it is concluded that the specific fuel consumption was increased approximately 1 percent by the nacelle modification.

Performance data obtained during the nacelle structural integrity tests are included in figures 16(a) and (b) for all four sets of modified inlets and exhaust ducts. As was mentioned before, the wind limit for accurate performance measurements was not observed during these tests, and the data are therefore less accurate than those of figure 15. It was concluded from figure 16 that no important differences in nacelle performance existed among the four sets.

Although figure 15(a) indicates little if any reduction in gross thrust at a constant EPR, a reduction in thrust ratings for the modified nacelle would be required because of required reductions in rated EPR settings. These reductions were required for two reasons. First, for airplanes equipped with the existing nacelles, an increase of EPR at ratings over that specified for the basic engine was allowed. This small increase was available only with the particular fan-exhaust duct and fan-thrust-reverser arrangement supplied with the engine for the existing nacelles, and was not available for the modified nacelles.

Second, a more significant adjustment in EPR would be required to prevent engine overboost (turbine inlet temperature increase) due to inlet loss. Analysis of the test stand data obtained in the P&WA tests indicated that the turbine inlet temperature was increased approximately 25°F at a constant EPR due to the installation of the modified inlet. The revised rated EPR settings required to account for the two factors discussed above are presented in figure 17.

Both the McDonnell Douglas and P&WA tests indicated no effect of the modified nacelle on engine starting, acceleration, and deceleration characteristics. In addition, no engine surges were experienced when the modified nacelle was operated throughout its complete range of power under simulated cross winds up to 35 knots.

Structural Integrity Tests

Several types of structural integrity tests were devised so that no structural deficiencies of the flight modified nacelles would endanger the flight test airplane or engines.

Procedures. – The structural-integrity testing conducted by P&WA was primarily concerned with an evaluation of the engine fan disk and blade stresses and was restricted to ensuring safe engine operation. The engine used for these tests was specially instrumented for fan stress measurements, and was the same engine used for the performance and operational tests. The structural-integrity testing conducted by McDonnell Douglas was concerned with both evaluating inlet-ring vibrational characteristics and providing an operational proof test of each set of modified inlet and fan-exhaust ducts.

An investigation of the vibration characteristics of the inlet ring revealed resonance frequencies at 60, 96, and 147 Hz. For the structural integrity testing of the first modified flight inlet, eight high-frequency accelerometers were provided at the base of the support struts, and at the leading and trailing edges of the rings. Acceleration limits at the strut supports were set to correspond with a maximum ring deflection of 0.125 inch, assuming pure sinusoidal motion at the resonance frequencies. The basis for this limit was the maximum out-of-plane deflection limit of 0.125 inch described in reference 3 for all assemblies.

Figure 18 illustrates the sequence of engine operations used to subject each flight modified nacelle to a broad range of operational characteristics. Using this test procedure assured that each set of flight nacelle ducts would be subjected to the full spectrum of simulated flight conditions available on the static test stand.

Results. – Throughout the P&WA stress testing of the flight modified nacelle, no significant increase in engine first-stage fan-blade stress or first- and second-stage fan-blade disk stresses was indicated. However, the results of the P&WA stress testing of the modified nacelle indicated a substantial increase in second-stage fan-blade stresses relative to those observed with the existing ducts. The dominant stress occurred at a frequency equal to three times the N_1 rotor speed ($3N_1$). Although this stress increase occurred at an N_1 rotor speed of 7100 rpm, i.e., 250 rpm greater than the existing N_1 limit, the higher peak stress at maximum rpm and the resultant increased stress-hysteresis curve effectively shifted the slope of the $3N_1$ peak stress downward in speed, producing higher second-stage fan-blade stresses in the vicinity of the existing N_1 limit. Based on the results of these tests, P&WA recommended that the existing engine N_1 limit of 6850 rpm be reduced by 100 rpm for the flight tests to prevent possible over-stressing of the second-stage fan blades.

Although the reduced N_1 limit would not affect normal service operations, it would reduce the existing operating margin and further tests would have to be performed to eliminate the stress increment. The source of the problem is not readily apparent, though it may be associated with the detailed aerodynamic design of the fan-exhaust-duct treated splitters near their leading edges.

Because the existing N_1 limit would not be encountered during normal service or flight test operations with either the existing or the modified airplanes, no restrictions on the flight test operations were imposed by the modified N_1 limit of 6750 rpm.

During initial static engine tests of the modified flight inlets, the broadband inlet ring accelerations exceeded the acceleration limits at engine low-power operations. The concentric ring was modified by filling its hollow leading and trailing edges with a room-temperature vulcanizing rubber compound. Subsequent testing at various engine power settings showed that all resonance frequencies were damped and accelerations were within the allowable limits. The other three flight-inlet concentric rings were similarly modified and the inlets were successfully tested with no vibrational problems noted.

During the first inspection of the first flight nacelle inlet (prescribed in the structural-integrity engine operations sequence) an area of bonding failure in one-half of the inlet duct was discovered. Detailed inspection of the inlet duct, centerbody, and concentric ring revealed the extent of the area of failure to be approximately 5 square feet and limited to the bond between the honeycomb core and the fibermetal facing sheet in one-half the inlet duct only (see fig. 19). The bonding failure was attributed to loss of bonding pressure during the bond-cure cycle. All acoustical treatment in the damaged half of the inlet duct was removed and replaced with new material. The repaired inlet duct was subsequently retested for structural integrity with no further failures noted.

During installation of flow splitters in the fan-exhaust ducting set No. 2, a manufacturing irregularity caused delamination of the porous metal surface and the honeycomb core. The two affected areas covered approximately 12 and 18 square inches. Repairs were accomplished using techniques similar to those described in reference 3. This involved reattaching the porous metal surface with mechanical fasteners and bisecting both failures with a splitter assembly. Both repairs functioned adequately throughout ground test and flight test operations. No further problems with bonded assemblies were encountered.

FLYOVER NOISE TESTS

Although the principal objective of the flyover noise tests was to measure the noise under the flight path, measurements were also made under and to the side of the takeoff flight path to determine the overall noise-reduction potential of the modified engine nacelles. Measurements under the initial-climb flight path were made by using full-rated takeoff thrust and by using reduced thrust to simulate reduced-thrust climbouts. Tests were conducted such that the basic results could be expressed in terms of airplane height, airspeed, engine power setting, and distance from the runway.

Test conditions included takeoff and landing operations over a range of gross weights for both the existing and modified airplanes. Flyover noise was measured for a total of twelve different flight conditions (test items), which are listed in test sequence in table VI.

Test Procedures

Flyover noise measurements were acquired by ten recording stations, which were moved about as required. Emphasis was placed on the recording of sound data directly beneath the airplane flight path for each airplane operation at heights from 300 to 3600 ft for takeoff and 200 to 2800 ft for landing. In addition, 1500-ft sideline data were recorded for the takeoffs, at the start of roll and during initial climbout at airplane heights of 130 to 1800 feet.

Sound station and aircraft test procedures were identical for the existing and modified aircraft configurations, except for changes in takeoff engine-power setting and in station locations. For the modified engine nacelle, the takeoff-rated EPR setting was 1.84 (figure 17) to an ambient temperature of $84^{o}F$ instead of an EPR of 1.87 as permitted for the existing airplane. Some of the sound station locations were changed for the modified nacelle tests to (a) acquire more recordings for some test items, (b) more effectively avoid recording flyover noise as engine power was being changed during the start of climb at reduced thrust, and (c) reduce the time required for some sound stations to change location.

Test site. – All flyover noise testing was accomplished in the vicinity of the Fresno Air Terminal in Fresno, California. All flyover noise tests utilized the primary runway, which was 9200 feet long and incorporated an Instrument Landing System (ILS) for an approach glide-slope angle of 2.5 degrees. The ground beneath the flight path was relatively flat with an elevation of 335 ft ±15 ft and was generally uniform acoustically. The area southeast of the airport was used to conduct both takeoff and landing operations. The locations of the sound stations were devoid of large obstacles, being comprised principally of agricultural surroundings (i.e., vineyards, orchards, and irrigated cropland).

Ambient noise levels at the test site (due to traffic, ground vehicles, equipment, etc.) should be at least 15 dB below the estimated peak aircraft noise levels in each 1/3-octave band. During testing, the actual ambient noise levels ranged from approximately 5 to 65 dB below peak flyover noise levels as shown by the 1/3-octave SPL differences of figure 20(a). Differences that were less than the desired 15 dB occurred in 1/3-octave bands at center frequencies of 8000 and 10 000 Hz for the takeoff and the simulated-takeoff tests at heights of about 3000 feet. Figure 20(b) shows the envelope of the ambient SPLs measured at all recording stations. The PNL corresponding to the maximum ambient SPLs was 73 PNdB, with an average of approximately 55 PNdB.

Quantity of recordings and measurement locations. – Acoustical testing was oriented toward acquiring sufficient data to obtain statistically valid average SPLs and to avoid the potential bias of a unique test environment on a given day. Douglas experience in previous flyover noise testing was utilized to define the test program shown in table VI. The sequence of tests was repeated on each of three scheduled test days. For each test day, the desired number of recordings were:

(a) For flight path centerline measurements, at least five recordings over the range of airplane heights for each test item (a minimum total of 15 for each climbout and each landing-approach); and

(b) For 1500-ft sideline measurements,

(1) Four recordings on one side of the flight path during one of the three climbouts with takeoff-rated thrust, plus one recording on the opposite side to verify symmetry of the sound field.

(2) Two recordings near the start of takeoff roll for any one of the three actual takeoffs. One recording at 1500 ft to the side of the start of roll and another at 1500 ft to the side and 1500 ft aft of the start of roll.

Ten mobile sound stations were utilized to acquire the desired number of sound recordings per flyover. The stations were moved about in a systematic manner to satisfy two needs:

1. Overhead and sideline noise recordings over the desired ranges of airplane height for the various flight profiles.

2. Minimal elapsed flight time per day to permit testing during acceptable weather conditions, which were typically of short duration (1.5 to 4 daylight hours).

The resultant layout of the locations is depicted in figure 21. Note that two stations (3 and 5) were located at a lateral distance of 2500 ft from the extended runway centerline, except, as shown in figure 21(b), that station 3 was at a 1500-ft sideline for only test item 1. Measurements made at stations 3 and 5 were considered equivalent to overhead measurements with minimum slant distances of about 3600 ft for takeoffs (at a height near 2400 ft) and about 2800 ft for landings (at a height near 1400 ft). With this choice of locations, the minimum ceiling required for satisfactory weather was about 2500 ft and the test range could be limited to a ground distance of about 8 statute miles from the start of the takeoff roll.

Airplane space-positioning concept. – A time history of the sound propagation distance between the airplane and each sound station was required so that test-day SPLs could be corrected for the differences in atmospheric absorption between the test-day conditions and the reference conditions of 59°F air temperature and 70-percent relative humidity. This task was accomplished using both airborne and sound-station instrumentation to determine the variation, with time, of the location of the aircraft. The distance from the airplane to the sound stations was determined to within ±10 percent. (A height variation of 10 percent corresponds to an SPL variation of approximately 1 dB.) Time correlation between the airplane and sound station recordings was required in this space-positioning concept.

Aircraft operation. – All takeoffs (test items 1, 5, and 9 of table VI) were flown according to a standard Douglas-recommended procedure, which is illustrated in figure 22(a). The only exception to this procedure was that takeoff-rated thrust was maintained to an altitude of 5000 ft, or for 5 minutes, whichever occurred first. Takeoff-rated EPR was used as the reference parameter for the full-thrust takeoffs. For test purposes, the reduced thrust simulated-takeoff procedure (test items 2, 3, 6, 7, 10, and 11 of table VI) was started from level flight along the centerline of the runway at a height of approximately 300 ft. Upon arriving at a selected point over the runway, engine power level was set to a predetermined low-pressure rotor speed and the airplane climbed out at a prescribed airspeed. Both the takeoffs and simulated takeoffs utilized the localizer beam and airplane heading for lateral displacement guidance.

The ILS approach and landing procedure (test items 4, 8, and 12 of table VI) is illustrated in figure 22(b). The major exception, and it differs from all normal airline operations, was that engine throttle settings were held nearly constant (to within ±2 percent N_1) throughout the approach to minimize variations in thrust and fan-noise frequency. This procedure produced comparable data on the different test days for each airplane configuration.

Takeoff EPR rating was used as the reference parameter for the takeoffs. This was done because PNL, though controlled by fan noise, was not considered to be sensitive to the N_1 rotor speed at or near takeoff thrust and engine thrust is the fundamental parameter with respect to takeoff-climb performance for a given airplane gross weight. The N_1 rotor speed was used as the reference parameter for the reduced-thrust simulated takeoffs and for the landings, as the N_1 rotor speed was considered to have the dominant influence on PNLs at moderate to low engine power settings on the existing nacelle.

Sound station operations. – Each station was equipped with a portable sound recording system that conformed to the requirements cited in reference 7. Six stations were also equipped with supplemental instruments for time-correlating station and airplane records and for measuring surface weather conditions. The equipment included in a typical sound-station system are pictured in figure 23 and listed in table VII.

The equipment was utilized as illustrated in figure 24. All equipment setups were similar at each station. The axis of the microphone varied from horizontal to nearly vertical, the intent being to obtain grazing incidence between the propagated sound and the microphone diaphragm. Thus, the diaphragm was always in the same plane as the line-of-sight from the sound station to the airplane and incidence corrections to the measured SPLs were not necessary. All microphones were set at a height of 5 ft above the ground. The axis of the camera was aligned with the line-of-sight from the sound station to the aircraft, the angle, at the time of photographing the airplane, being at or near vertical for overhead noise recordings and from nearly horizontal to 45 degrees for sideline recordings.

Sound-recording technique: A reference tone (from a pistonphone) with an SPL of 124 dB at a frequency of 250 Hz was recorded prior to each series of flyover noise recordings. Additional recordings of the reference tone were made during the tests as required. Estimated maximum overall SPLs determined the appropriate system gain settings to record the flyover noise. System gains were set such that the maximum noise level was 5 to 14 dB below the distortion level of the tape recorder. Each recording was begun and stopped so that the recording duration encompassed all airplane noise levels that appeared to exceed ambient levels.

Post-test calibrations: After the last test item of a test series was completed, each sound station recorded another reference tone. Subsequently, a frequency-response recording was made using each station's sound recording system. A constant-voltage stabilized sine-wave signal was recorded at the following ten frequencies: 50, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 10 000 Hz. These ten discrete frequencies were used to describe the frequency-response characteristics of the recording system for 1/3-octave-band data processing.

Time-correlation techniques: A photograph of the airplane was taken when it passed over or by each sound station. As the photograph was taken, a modified flash-mechanism on the camera actuated a synchronizing tone generator. The tone generator provided a signal to a synchronization track on the station tape recorder for all stations and to a station encoder for stations 1, 2, 4, 6, 7, and 8. This tone signal was transmitted by a VHF radio to the airplane via an encoder-oscillator (fig. 24) and recorded on both the photo-recorder and the oscillograph (fig. 10). Thus, for the six stations having encoders, all flyover noise tape recordings included a synchronization mark (the beginning of the tone signal) which was matched by a synchronization mark on the airborne recordings.

For the four stations without encoder-oscillators, time-correlation with the location of the airplane was achieved during data analysis by utilizing (a) the histories of airplane ground distance and the locations of the sound stations relative to the distance from the start of the runway, and (b) the synchronization marks on the tape recordings made when the airplane was photographed.

A secondary time-correlation technique was also employed. This was a manual system and utilized (a) voice communication, (b) a hand-held stopwatch, and (c) the reference-signal button on the station tape recorder.

Weather measurements: Both surface and low altitude weather were measured to determine compliance with the test criteria given in table VIII, and to provide the temperature and relative humidity measurements needed to correct the basic SPL data to reference atmospheric conditions.

Measurements of surface weather conditions were made at six sound recording stations. At 5- to 15-minute intervals, dry-and wet-bulb air temperatures were measured and tabulated by stations 1, 2, 6, 7, 8, and 10. Surface wind speeds and directions were measured immediately before and after each flyover noise recording, and the range of values was tabulated. All surface weather measurements were made at approximately the microphone height of 5 ft. At station number 6, spot checks of relative humidity (derived from a psychrometric chart by using measured dry- and wet-bulb temperatures) were made to determine if the atmospheric-absorption conditions were still desirable. Desirable conditions were defined as those resulting in a maximum difference at 8000 Hz of 5 dB/1000 ft between the absorption coefficients for test-day conditions and standard conditions (59^{o}F and 70-percent relative humidity), the coefficients being based on reference 8. Flyover noise measurements were occasionally permitted under conditions that were less than desirable, but not under conditions beyond those judged marginal, that is, equivalent to a difference at 8000 Hz of 9 dB/1000 ft between test-day and standard-day absorption coefficients.

Low-altitude soundings were conducted to determine the vertical distribution of temperature, humidity, and wind. Data were obtained under subcontract, using a small instrumented airplane, by the firm of Atmospherics, Inc. located in Fresno, California. The vertical sounding data were supplemented by U.S. Weather Bureau recordings of surface weather at the Fresno Air Terminal. Surface atmospheric-pressure data were obtained from the Weather Bureau recordings. The atmospheric soundings were conducted from the test-site surface to an altitude of 5000 feet. Measurements were made at altitude increments of 200 ft as the instrumented airplane circled upward over an area near the acoustical test range.

Data Processing

The techniques of processing flyover noise and airplane-and-performance data were common to both nacelle configurations and were consistent with currently accepted practices.

Acoustical data reduction. – The flyover noise recordings obtained at Fresno were reduced into 1/3-octave band SPLs with center frequencies from 50 to 10 000 Hz. The values of the 1/3-octave band SPLs during the flyovers provided the fundamental information needed to evaluate the modified nacelles. The SPLs were used to calculate instantaneous perceived noise levels (PNL), tone-corrected instantaneous perceived noise levels (PNLT), and effective perceived noise levels (EPNL).

The data reduction was accomplished with the analog-to-digital data-reduction system shown schematically in figure 25. Each flyover noise recording was reduced to histories of the SPL for the twenty four 1/3-octave bands by repeated playbacks of the analog tape recordings. The analog signal on the graphic level recorder was converted to a DC analog signal by a slide-wire potentiometer. An operational amplifier accounted for system gain adjustments required during the data reduction process and scaled the DC analog signals such that the indicated levels were in decibels re 0.0002 dynes/sq cm. The analog output of the operational amplifier was sampled at 0.25-sec intervals and converted into binary-coded-decimal (BCD) signals by a digital voltmeter. Using the coupler, the sampled BCD digital information was converted to decimal-coded information and transferred to a keypunch machine where it was stored on punched cards. The 0.25-sec interval was governed by the maximum practical operating rate of the keypunch machine.

The graphic-level recorder provided the damping in the data-reduction system. Damping of fluctuations in the flyover-noise signals was controlled by the lower-limiting frequency and the pen-writing speed of the level recorder. Based on previous experience, the recorder settings used for the reduction of all flyover noise signals were a 10 Hz lower-limiting frequency and a 16.25 dB/sec pen writing speed for all 1/3-octave bands.

The SPL data, system frequency-response correction factors, and microphone pressure-response correction factors for each flyover-noise recording were processed by a digital computer to determine the components of EPNL (i.e., PNL, tone-correction factors, and duration-correction factors).

Two computer programs to perform the required calculations were developed and utilized: one for test-day atmospheric conditions, and another for reference-day conditions of 59°F and 70 percent relative humidity. Both programs included (1) the methods of calculating EPNL as given in reference 9, (2) the mathematical formulations of the noy tables in reference 10 to calculate PNL, and (3) the details listed below to calculate duration-correction factors.

- The duration time was determined from the calculated values of PNLT as a function of time during a flyover. The duration time was defined by the points that were 10 PNdB less than the maximum value of PNLT (i.e., 10 PNdB less than PNLTM). If a 10-PNdB-down point did not coincide with a calculated value, then the duration time was taken as the difference between the initial and final times for which PNLT was nearest to the value of PNLTM minus 10 PNdB. For those cases with more than one PNLT peak, the applicable limits for the duration time were chosen so as to yield the largest-possible duration time.

- Duration-correction factors were computed by the integration method.

- The constants in the integration method were adjusted to account for the 0.25-sec interval used in sampling the flyover noise recordings.

A sample of the output from the test-day calculations is given in Appendix B for a selected flyover noise recording. Appendix C shows comparable results for reference-day atmospheric conditions.

The program for the reference-day calculations used the slant range distances from the space-positioning calculations to determine minimum distances, at 0.25-sec intervals, between the airplane and a microphone station. These minimum distances were used to determine atmospheric-absorption corrections using the method outlined in reference 8, based on surface temperature and relative humidity. The atmospheric-absorption corrections that had to be applied to the SPLs above 2000 Hz were large for long propagation distances. For example, at 8000 Hz the correction was as large as 81 dB for a slant range of 9000 ft (i.e., 9 dB/1000 ft).

Because of small signal—to—system-noise ratios at high frequencies (2000 to 10 000 Hz) and long slant ranges (greater than approximately 2500 ft), erroneous atmospheric-absorption corrections were applied to the background noise levels of the record/play back data system. For long slant ranges, these "corrected" background noise levels controlled the value of PNL for a large portion of the flyover history. Consequently, valid 10-PNdB-down points and hence valid duration times, as well as valid tone-correction factors, could not be determined. An example of the problem with background noise levels is illustrated by figure 26, which shows the variation of PNLT with time for a low-altitude landing and a medium-altitude takeoff. For some power settings and distances other than those of figure 26, the analysis was subject to even more severe problems.

The schedule of the present study program did not permit a revision of any data-reduction or data-analysis procedures. Thus, it was not feasible to determine valid EPNLs under reference-day atmospheric conditions. On the other hand, reference-day PNLM values could be determined because the propagation distances and the signal—to—system-noise ratios, at the time of PNLM, were not within the range of the adverse combinations.

Acoustical data analysis. – The numerous measurements of the EPNL components (obtained from flyover noise recordings) were used in two ways. First, the EPNL components from all of the recordings for each engine power setting were used to develop generalized EPNLs. Second, EPNLs were calculated for each recording (i.e., single-point analyses). The generalized approach was used to provide detailed information for evaluation of the changes in flyover noise levels that were produced by the acoustically treated nacelles and also to provide data that are more versatile regarding the application of the test results to a wide range of operational conditions. The single-point approach served to check the validity of the generalized results. For both approaches, the resultant data were analyzed as a function of airplane slant distance and engine thrust setting.

The procedure for determining generalized flyover noise levels for the existing and modified nacelles consisted of the following six steps: (1) for each 1/3-octave band, plot the individual SPL values, occurring at the time of PNLM, versus their respective values of slant distance and then fair mean lines through the data points on a least-square basis; (2) for each engine power setting, calculate values for PNLM as a function of slant distance by using appropriate values of 1/3-octave-band SPLs read from the faired values of SPL versus slant distance determined in step 1; (3) plot individually calculated values of the difference between PNLTM and PNLM as a function of slant distance and thrust and determine a generalized form of a tone-correction factor; (4) plot individually calculated duration-correction factors as a function of slant distance and thrust to determine a generalized form for a duration-correction factor; (5) for each engine power setting, combine appropriate values for PNLM from step 2 with a tone-correction factor (PNLTM-PNLM) from step 3 and a duration-correction factor from step 4 to determine generalized values of EPNL as a function of slant distance; and (6) for each engine power setting, check the validity of the generalized EPNLs determined in step 5 by comparison to plots of individually calculated EPNLs as a function of slant distance.

Airplane space-positioning analysis. – A description and the source of derivation for each space-positioning parameter is given below.

- Ground distance: the distance along the airplane flight path relative to the brake release point at the beginning of the runway. Ground distance was determined by using (1) the integral of true airspeed over various discrete intervals of time, (2) time-correlation signals transmitted by the six stations under the flight path, (3) the radio signals from the ILS marker beacons, and (4) the distances of the sound stations and the ILS beacons from the start of the runway.

- Height: the vertical distance of the airplane above the runway elevation, based on the airplane radio and pressure altimeters.

- Localizer deviation: the lateral distance of the airplane from the localizer beam of the ILS. Localizer deviation was based on signals given by the localizer beam and recorded on the airplane oscillograph.

- Slant distance: the minimum distance in the vertical plane from the center of the airplane to the extended centerline of the runway, derived geometrically from the height and localizer deviation cited above and from the slant distances based on the airplane photographs taken at the sound stations under the flight path.

- Slant range: the distance between a sound station and the airplane for the duration of a sound recording, based on (1) the slant and ground distances of the airplane and (2) the ground position of the sound stations.

The geometry involved in space positioning is illustrated in figure 27. The determination of slant distance, as shown in figure 27 and defined above, revealed discrepancies between values determined with airplane instrumentation data and sound-station photograph data. These discrepancies were on the order of 100 to 400 ft and necessitated a comprehensive and detailed evaluation of the results. This evaluation led to the conclusion that the photograph distances were more reliable than the airplane instrumentation data. Consequently, the continuous flight paths based on airplane instrumentation were adjusted to coincide with the photograph distances to within ±10%, as illustrated in figure 28. These adjusted flight paths were used to determine the slant ranges required for atmospheric-absorption corrections to obtain reference-day PNLMs.

Airplane and engine parameter derivation. – All basic data for the airplane and engine conditions were tabulated manually from the airplane instrumentation recordings. These data and the calibration/correction values were computer-processed to provide corrected airplane and engine data such as true airspeed and derived values such as ground distance.

Weather data processing. – The sound station measurements of surface temperature (dry- and wet-bulb) were used to determine the surface relative humidity from standard psychrometric charts. For each flight, measured temperature histories were prepared and the data were faired as illustrated by figure 29. These fairings were used to determine the average surface weather values for each test item and were applicable to the sound recordings of all stations for each item. The surface wind measurements were processed in a similar manner to determine the average values of wind speed and direction.

Data describing the temperatures, the humidities, and the winds, all aloft, were processed by the subcontractor who conducted the low-altitude soundings.

Results and Discussion

Flyover noise data were acquired for the existing and modified nacelles under similar acoustical and atmospheric conditions.

Data repeatability. – The estimated degree of repeatability (within two standard deviations) for the faired data is given below for each test parameter related to the flyover noise evaluation.

One-third octave-band SPLs:	±1.5 dB
Surface temperature:	±1 degree
Surface relative humidity:	±4 percent
Airplane slant distance:	±10 percent
Airplane airspeed:	±4 kn
Engine N_1 speed:	±1 percent
Engine thrust:	±400 lb/engine
Time correlation:	±1.5 seconds

Ambient surface weather. – On each test day, variations in surface air temperature, humidity, and wind were relatively small during the flyover-noise test hours. For the tests with the existing nacelles (conducted in February 1969), the ambient air temperatures ranged from 48° to 65°F with corresponding relative humidities of 84 to 40 percent. For the tests with the treated nacelles (conducted in March 1969), the corresponding temperature and relative humidity values were 43° to 57°F and 81 to 53 percent, respectively. The absolute humidity of the air near the surface ranged from 5.8 to 7.5 gm/m^3 for all tests. Prevailing surface winds ranged from calm to 10 mph.

Ambient weather aloft. – The predominant atmospheric conditions between the surface and 5000 ft height were of qualitative interest. The overall results of the soundings are given in figure 30. In general, the weather aloft was favorable except for the frequent moisture inversion at approximately 2000 ft for the tests with the existing airplane. The effect of this moisture inversion was not determined. It should be noted that dew point information was provided because of its versatility regarding the use of meteorological charts and, in turn, the potential for an investigation of meteorological effects at some later date.

Airplane and engine conditions. – The target and actual test values of airplane and engine conditions were compared. The comparison was made to determine the degree of test consistency and to evaluate the acoustical effects of variations from the scheduled test conditions. The average test conditions were acceptably close to the target conditions and are given in table IX. Also, the fluctuations were small enough such that the acoustical effects were not significant, except for some landing tests and the initial part of the simulated takeoff tests with reduced thrust. During the landings judged to be invalid, engine stability and the ILS flight path (with target conditions) could not be maintained simultaneously. For the simulated takeoffs, invalid flyover noise recordings often occurred at the beginning of the flyover as the engine power was being set; this resulted from the difficult pilot task of conducting the initial portion of the simulated maneuver over a selected point on the ground.

Flyover noise data. – This section presents the basic flyover noise levels derived from the measured 1/3-octave-band SPLs. The results are presented in a generalized form as a function of slant distance and engine thrust setting for the existing and modified airplanes. These generalized results were subsequently used to determine generalized community noise levels. As mentioned in the data analysis section, the calculation of reference-day EPNLs was not feasible. Consequently, the presentation of results for reference-day atmospheric conditions is restricted to PNLMs in this report, and most of the data herein are PNL and EPNL results for test-day conditions. The use of test-day results, to determine the magnitude of flyover noise reductions, is acceptable because the weather conditions were acoustically equivalent for the tests of the existing and modified nacelles.

Three types of basic information are presented in this section: (1) SPLs, PNLMs, and EPNLs for test-day atmospheric conditions; (2) PNLMs for reference-day atmospheric conditions; and (3) comparisons of measured and predicted SPLs and PNLs for the airplane equipped with modified nacelles.

Test-day data: Evaluation of aircraft flyover-noise levels in terms of EPNLs requires consideration of the variation of the sound pressure levels and perceived noise levels with time during a flyover. Figure 31 shows sample plots of PNL as a function of relative time for a nominal slant distance of 400 ft at a landing thrust setting and a nominal slant distance of 1000 ft for a takeoff thrust setting. The time scale on the abscissa is relative to the time of occurrence of the maximum perceived noise level, i.e., to the time of PNLM. The time of PNLM does not necessarily correspond to the time when the airplane was over the microphone.

Figure 31 indicates that substantial reductions in PNL were obtained throughout the entire PNL history during the landing-approach flyover. The reductions in PNL at the takeoff thrust setting were not large near the peak of the PNL history, although some significant reductions were obtained before and after the peak.

The large change in the PNLM at the landing-thrust setting was due to substantial reductions in the SPL of the discrete-frequency components of the noise from the existing nacelles. Typical SPL spectra at the time of PNLM are shown in figure 32. At the landing power setting, figure 32(a), there was a 20-dB reduction in the SPL in the 2500-Hz band; there was a 10-dB reduction in the SPL in the 5000-Hz band. The fundamental blade-passage frequency is in the 2500-Hz band at this power setting; the second harmonic is in the 5000-Hz band. Essentially no change occurred to the portion of the spectrum below 800 Hz that is controlled by jet-exhaust noise.

At the takeoff power setting, figure 32(b), there was approximately a 10-dB reduction in the SPL in the 3150-Hz band, but little change to the SPLs in the bands below 2500-Hz that are dominated by jet-exhaust noise. Because the jet-exhaust noise controls the PNL of the modified nacelles, the reduction in PNLM was smaller at the takeoff-thrust setting, figure 31(b), than at the landing-thrust setting.

Figures 33 and 34 show samples of the variation with slant distance of the 1/3-octave-band SPLs used to calculate generalized PNLMs. These SPLs, like those shown in figure 32, were those occurring at the time of PNLM. In figure 33, for a landing thrust setting, the SPLs are shown for the 2500- and the 5000-Hz 1/3-octave bands because the SPLs in these bands dominate the perceived noisiness of either the existing or the modified airplane throughout the range of distance illustrated. Figure 34 presents data for the SPLs in the 3150-Hz and the 315-Hz bands for a takeoff thrust setting. For the existing nacelles, the noisiness of the SPL at the fundamental blade-passage frequency in the 3150-Hz band dominates the PNL at the low altitudes; at high altitudes, the noisiness of the SPLs in the frequency region around 315 Hz from the jet-exhaust noise determines the PNL. The second harmonic of the fan-blade-passage frequencies in the 6300-Hz band makes a negligible contribution to the total noisiness at the takeoff thrust setting.

The variation of generalized PNLM with slant distance is presented in figure 35 for five different thrust conditions. The thrusts are the values of the average referred installed net thrust for the conditions of the flyover noise tests. Results for five instead of the six thrust settings indicated in table VI are presented because the SPLs resulting from the analyses of the recordings of the data for test items 8 and 12 could not be resolved into two separate families. The actual engine power settings used for test items 8 and 12 were not as widely separated as had been planned. The dashed portions of the curves indicate ranges of slant distance where there were fewer SPL measurements and, hence, where there is less confidence in the results.

An illustration of the repeatability of the PNLM values shown in figure 35 was obtained from examination of curves of SPL vs slant distance similar to those shown in figures 33 and 34. Considering the envelope of the lines that could be drawn through the data available, it was estimated that the scatter in the SPL data would result in maximum deviations of ±1 PNdB around the mean PNLM values shown in figure 35 for the landing power settings and approximately ±1.5 PNdB around the mean PNLM values for the takeoff power setting.

The generalized values of the tone-correction factor (PNLTM-PNLM) are shown in figure 36. Examination of all the test data available showed that this quantity (PNLTM-PNLM) was essentially independent of slant distance for the five engine-power settings. As was anticipated, the (PNLTM-PNLM) differences were larger for the existing nacelles than for the modified nacelles because the intense discrete tones at the blade-passage frequencies with the existing nacelles yielded large tone corrections to the PNLs. The differences were also larger at the landing power settings because the tones were more prominent at the landing than at the takeoff power setting.

The generalized values of the duration-correction factor, D, are given in figure 37. In contrast to the (PNLTM-PNLM) differences, the duration-correction factor was independent of engine-power setting and was principally a function of the slant distance. The results shown in figure 37 represent mean values derived from analysis of all of the individually determined duration-correction factors. The duration-correction factors for the modified nacelles were approximately 1 dB larger than those for the existing nacelles. There was no discernible effect of airspeed variations on the duration-correction factors, and, hence, none on EPNL.

Generalized EPNLs for the existing and the modified nacelles were determined from the PNLM data given in figure 35, the (PNLTM-PNLM) differences given in figure 36, and the duration-correction factors given in figure 37. The results of these analyses are given in figure 38. The dashed lines have the same significance as for the PNLMs of figure 35.

Samples of the individual (single-point) EPNL test results compared to the generalized results of figure 38 are shown in figure 39 for the existing and the modified nacelles. Figure 39(a) shows results for a landing thrust setting, figure 39(b) for a takeoff thrust setting. For both cases the variation of the individual EPNL values from the generalized lines was within ±1.5 EPNdB. For the simulated takeoffs with reduced thrust, the variations were larger and were within ±3 EPNdB.

Evaluation of the noise of a retrofitted airplane under operational conditions (discussed in the next section) requires combining the EPNL information given in figure 38 with flight path information for a given airplane gross weight. Since the thrust required is a function of gross weight it was also necessary to develop plots of the variation of EPNL with installed net thrust for constant slant distances. Samples of such plots are given in figure 40 for a distance of 370 ft under the landing approach path and 1000 ft under the initial-climb path. The ranges of thrust per engine required for landing approach, climbout at reduced thrust, and climbout with rated takeoff thrust are indicated on the graph. The indicated variation in takeoff thrust is a result of the variation of airspeed with gross weight, as well as the difference in takeoff-rated thrust between the modified and existing nacelles.

In addition to overhead noise measurements, the flight tests included measurements [fig. 21(b)] of the flyover noise at locations along a line 1500 ft to the side of the takeoff flight path for test item 1, the highest gross weight. The results of these sideline measurements are presented in figure 41. The maximum EPNL values occurred when the airplane with existing nacelles was at a height of about 900 ft and with the modified nacelles at a height of about 1100 ft.

The noise measurements made at the start of roll [see fig. 21(c)] were examined to determine the change in PNLM at the two test stations. (PNLM was used here instead of EPNL because the duration corrections have no significance for these measurements.) There was no significant difference in the PNLM, at either station 9 or station 10, between the existing and modified nacelles. At station 9, 1500 ft to the side of the start-of-roll point, the average PNLM was 102 ± 2 PNdB. At station 10, 1500 ft to the side and 1500 ft behind the start-of-roll point, the average PNLM was 100.5 ± 1.5 PNdB.

These PNLMs were less than those that were measured along the 1500-ft sideline after the airplane had lifted off the runway during the start of the takeoff-climb (i.e., less than PNLMs of 109 and 106 PNdB, for the existing and the modified airplanes, respectively). Thus, the maximum noise level on the 1500-ft sideline occurred after liftoff and not at the start of roll.

Reference-day data: Figure 42 shows the PNLMs that were obtained for reference-day conditions over the range of aircraft slant distances and engine power settings for the existing and the modified nacelles. The results shown in figure 42 are similar to those given in figure 35 except that the reference-day PNLMs are higher than the test-day PNLMs because of the atmospheric-absorption corrections that have been made.

Comparison of measured and predicted values: The flyover-noise data obtained in this program afforded an opportunity to validate the flyover-noise estimation method that was described in reference 4. Figures 43 and 44 show comparisons of measured and predicted PNLs and corresponding SPLs at the time of PNLM, for two flight conditions with the modified nacelle. The conditions were a landing power at a nominal 400-ft slant distance and a takeoff power at a nominal 1000-ft slant distance. The predictions used the static 150-ft SPL data given in Appendix A. As in figure 31, the measured and predicted PNLs were both plotted relative to the time of their respective PNLMs. The predicted PNLs (dashed lines) were adjusted to the engine conditions of the measured PNLs.

The measured and predicted values of SPL and PNL agreed reasonably well for both nacelle configurations considering the difference in the SPL spectra for the existing and modified nacelles and the fact that the prediction technique was developed on the basis of the spectra of the noise from the existing nacelles. However, the technique could be altered to improve the agreement in the low-frequency region controlled by jet-exhaust noise. The differences between the shapes of the measured and the predicted PNL histories in figure 43 would result in minor differences in the integrated duration-correction factors for EPNL calculations. Further efforts would be required to develop a more complete prediction technique, particularly if it is to be applied to engines other than the P&WA JT3D-3B and to nacelle acoustical treatments other than that tested in this program.

TEST AIRPLANE PERFORMANCE AND OPERATIONS

Both the existing and modified nacelle configurations were tested to determine if the nacelle modifications affected airplane cruise performance or operating characteristics.

Test Methods and Instrumentation

Cruise performance. – Airplane cruise performance was measured in terms of airplane range factor at constant referred gross weights (W/δ_{am}) of 800 000, 950 000, and 1 100 000 pounds. For each nacelle configuration, a total of 10 to 14 test points were measured at each value of W/δ_{am}. These tests covered a speed range of 0.68 to 0.86 Mach number, an altitude range of 28 000 to 35 000 feet, and an airplane gross weight range of 220 000 to 280 000 pounds. Range factor is defined as the ratio of the product of true airspeed, in knots or n. mi./hr, and the aircraft weight, in lb, to the total fuel flow, in lb/hr.

All cruise performance tests were flown in areas of meteorologically stable air masses to assure stabilized data. For each test point, the preselected W/δ_{am} value was established by flying at that altitude which yielded the proper value of δ_{am} for the actual airplane gross weight. Engine power was then set on each engine to obtain the desired Mach number. After the airplane flight conditions had stabilized, the airplane was flown for a minimum of 3 minutes without power adjustment.

Stabilization was determined for each test run by inflight plotting of altitude, airspeed, and ram air temperature at 15-second increments. If variations in any of these parameters were excessive, the run was either extended until the parameters were stabilized or discontinued and repeated in an area of more stable atmospheric conditions. While setting up the conditions for the next test run and to verify the quality of the data recorded on the previous run, the observed range factor was plotted versus Mach number.

Production airplane instrumentation and test instrumentation, as described in table IV, was used to measure the airplane cruise performance. All relevant instrumentation was calibrated prior to and immediately after the cruise performance tests of each configuration.

The aircraft was weighed immediately prior to each cruise-performance flight. These weights, in combination with short-interval periodic recordings of in-flight fuel quantity, allowed an instantaneous determination of the W/δ_{am} to set up the test conditions. These data, in conjunction with similar post-flight airplane weighings, were used to establish an accurate history of the gross weight for subsequent data analysis.

During airplane weighing operations, fuel samples were taken and analyzed to determine the fuel density (using the density-temperature relationship provided by the American Petroleum Institute), viscosity, and fuel heat content. The values obtained for density and viscosity were used in conjunction with the volumetric flow-meter data to calculate fuel mass-flow rate. The heat content was used to verify that the fuel used in each of the runs was equivalent in heat content and within the tolerance allowed by the fuel specification.

Engine operations. – Standard engine fuel-control adjustment procedures were accomplished for all engines prior to testing the existing nacelles. Minimum allowable engine idle speeds were set for satisfactory engine operations. The same fuel control settings were used with the modified nacelles.

Total pneumatic system leakage rates were measured and were equivalent for both the existing and modified nacelle installations.

The engine operating characteristics were qualitatively evaluated during the course of the flight test program to determine if the modified nacelle had any adverse effect on engine operations. Engine operating parameters for both nacelle configurations were measured during cruise flight conditions over a wide range of engine power settings for comparison between the two configurations. Engine airstarts were performed, with the modified nacelles installed, at altitudes ranging from 5000 ft to 35 000 ft to determine the effect of the nacelle modification within the FAA-approved JT3D-3B airstart envelope.

Engine acceleration characteristics were evaluated following each airstart and during low-altitude landing approach conditions to determine if the modified nacelle installation had any adverse effect on engine operation during acceleration.

The instrumentation used to evaluate engine operation consisted of calibrated production and flight instruments to measure compressor rotor speeds, exhaust-gas temperatures, engine pressure ratios, exhaust-gas total pressures, and engine fuel flows. For the modified configuration, thermocouples were installed to measure temperatures on six selected critical engine components:

- Fuel control body
- Engine-driven fuel-pump body
- Ignition-exciter-box mounting bolt
- 28-volt-dc ignition and accessory harness
- Ignitor plug cable, 3-in. forward of ignitor
- Ambient air adjacent to pylon wire harness.

Data Processing

Histories of airspeed, altitude, and total air temperature were prepared and a data fairing made to determine the stabilized part of each run. Engine gas-generator data were corrected for instrument error and to reference atmospheric conditions and then compared to applicable generalized engine curves to verify proper engine operation. Using the weight-time plot, exact determinations of W/δ_{am} for the selected data segments were obtained. These data were processed using a digital computer to standardize to the selected W/δ_{am} conditions. The calculated airplane range factor was corrected for kinetic and potential energy changes due to minor variations in airspeed, altitude, or ram air temperature which occurred during the stabilized run.

The evaluation of the engine operations in the modified nacelle configuration was accomplished by a comparison of the existing and modified nacelle data, that is, the engine operating parameters N_1, N_2, EPR, and w_f, referred to standard day conditions.

Results and Discussion

Cruise performance. – The range of W/δ_{am} tested was satisfactory in that it quantitatively defined airplane performance in terms of range factor as a function of Mach number. The results indicated a significant gain in cruise performance for the modified nacelle. Range factor as a function of Mach number for each value of W/δ_{am} tested is shown in figure 45. The corresponding percentage change in specific range [(range factor)/(W/δ_{am})] is shown in figure 46. At a nominal cruise Mach number of 0.82, the modified nacelle configuration showed a gain in specific range of from 1.5 percent to 4.5 percent over the range of referred gross weights tested. The average increase in specific range at this Mach number was 3 percent. Since the test airplane was not instrumented to measure flight thrust or drag, the source of this improvement cannot be identified directly. However, the specific-range improvement indicated by the flight tests together with the results of the nacelle static tests (fig. 15), which showed a small increase in SFC, led to the inference that the drag of the modified airplane was approximately 3 percent less than the drag of the existing airplane at Mach numbers above approximately 0.6. The improvement in cruise performance with the modified nacelle is the result of the change in thrust-minus-drag due to the 24-inch increase in the length of the fan exhaust ducts.

Engine and airplane operation. – A comparison of the primary parameters affecting normal engine operation is shown on figure 47. The referred low- and high-pressure rotor speeds and fuel flow were determined at cruise flight conditions (nominal 0.8 Mach number) for a wide range of EPR. The engine performance as a function of EPR was noted to be essentially the same for both nacelle configurations.

The FAA-approved JT3D-3B airstart envelope was unaffected by the nacelle modification. Engine operation was normal during shutdown and restarting in both nacelle configurations at all flight conditions checked (see fig. 48). Engine accelerations were performed without encountering compressor stall, surge, or any other adverse operating characteristic.

Low-pressure rotor speeds were recorded during rapid engine-acceleration tests in the landing-approach configuration. The results showed that there was no significant difference between the engine acceleration characteristics of the two nacelles.

The critical engine component temperatures monitored in the modified nacelle configuration did not exceed the manufacturer's limits during either ground or flight operations.

A crosswind landing was accomplished with a crosswind component velocity of approximately 20 knots without experiencing any adverse engine operation, thrust loss, or engine surge.

The operating procedures, cockpit workload, and crew safety were not affected by the nacelle modification. A significant reduction in cockpit noise levels during the landing approach was subjectively noted in the modified airplane. Qualitative flight crew evaluations indicated that this noise level reduction improved voice communication in the cockpit when using overhead loudspeakers during landing approach.

EVALUATION OF THE RETROFITTED AIRPLANE

The results of the ground testing and the flight testing were used to evaluate the general flyover noise, aerodynamic performance, and operational aspects of a Douglas DC-8-55 airplane equipped with a commercial (retrofit) version of the modified nacelles. The emphasis of the evaluation was on the changes to be anticipated during normal commercial airline service.

Flyover Noise Levels

The previous section presented the basic results of the flyover noise tests on an existing and modified DC-8-55 test airplane. The test results indicated that the nacelle modification produced measurable and significant reductions in flyover noise levels. This section of the report presents evaluations of these results in terms of assumed operational procedures for landing approaches and takeoffs. Although actual airline operating procedures may not be the same as those assumed here, the effects of the nacelle modifications on flyover noise levels are considered representative of those that could be obtained in practice with retrofitted DC-8-55 airplanes. Evaluation of specific situations other than those discussed here can be made from the basic results that were presented for the test airplane by using procedures similar to those discussed below.

Flyover noise data were evaluated principally in terms of EPNL for landing approaches, rated-thrust takeoffs, and reduced-thrust takeoffs. The EPNLs were determined for the test-day atmospheric conditions shown in figure 30. For purposes of comparing the acoustical performance of the modified nacelles to the 7 to 10 PNdB design goal, evaluations of the nacelle modifications are also presented in terms of reference-day PNLMs.

The airplane flight paths assumed for these evaluations accounted for the effect of the nacelle modification on installed net thrust. Further, it was assumed that the runway was at sea level, that the air temperature was 59°F, and that there was no wind. The takeoff and initial-climb flight paths were determined for a climb airspeed of V_2 + 10 kn, a reference payload of 30 175 lb, and a 25-degree flap setting.

Landing approach. – A 3-degree flight path to a 50-ft height over the threshold of the runway was assumed for the landing-approach flight path. The installed net thrust per engine required to fly along the 3-degree path is shown in figure 49 for two operational DC-8 landing flap settings. The landing thrust settings in figure 49 cover an operational range of landing weights and apply to both the existing and the modified nacelles.

The variation of EPNL with distance from the landing threshold was determined for two landing gross weights and the attendant thrusts required with the landing flaps fully extended. The results are shown in figure 50 for the existing and the modified nacelles. The 240 000-lb weight is the maximum certified landing weight for DC-8-55 airplanes; the 180 000-lb weight is representative of a light landing weight.

As shown in figure 51, the noise reduction was approximately constant at locations under the flight path and near the airport. For the 240 000-lb airplane, the reduction achieved was 10 to 10.5 EPNdB to a distance of nearly 5 n. mi. from threshold and then it gradually decreased with increasing distance from threshold. The noise reduction achieved by the 180 000-lb airplane was larger than that achieved by the 240 000-lb airplane to approximately 8 n. mi. from threshold.

At a location 1 n. mi. from threshold (i.e., the location under the landing-approach flight path that was specified in reference 11 for use in certifying the flyover-noise levels of jet transports), the airplane on a 3-deg landing flight path is about 370 ft above the ground. Figure 52 shows the variations of EPNL, for a 370-ft distance, over a range of landing weights. At 240 000 lb, the reduction was 10.5 EPNdB (from 117.5 to 107 EPNdB); at 180 000 lb it was 12 EPNdB (from 114.5 to 102.5 EPNdB). The noise reductions were greater for the lighter weights because of the smaller contribution of jet-exhaust noise at the lower engine-power settings.

Initial climb with takeoff-rated-thrust. – Takeoff and initial-climb flight paths are shown in figure 53 for four takeoff gross weights. The V_2 + 10 kn climb speed is a function of the weight and other parameters and, for the conditions assumed, varies from approximately 150 kn for the 850-n. mi. range to 174 kn for the 325 000-lb takeoff weight.

The ranges selected for illustration in figure 53 were 850, 1700 and 2500 n. mi. The 850-n. mi. range represents the average domestic range flown by four-engine jet transports in the U.S.A. The other two ranges represent major ranges in the U.S.A. in terms of the number of departures. The flight path for the 325 000-lb maximum certificated takeoff gross weight is shown because maximum weights were proposed in reference 11 for certifying flyover noise levels under the takeoff and initial climb flight path. Figure 54 shows takeoff gross weight for the existing and the modified airplane as a function of range for domestic operating rules and for takeoffs with the reference payload.

The variation of EPNL under the takeoff flight path is shown in figure 55 for two takeoff gross weights. At a given distance from brake release, the modified nacelles reduced the EPNL by 1.5 to 4 EPNdB. At the location specified in reference 11 of 3.5 n. mi. from start of takeoff roll, the 325 000-lb airplane with the modified nacelles reduced the EPNL by 3.5 EPNdB. For the airplane with the 2500-n. mi. range, the reduction at 3.5 n. mi. was approximately 1.5 EPNdB, although the values of EPNL were considerably lower at this weight (104 to 105.5 EPNdB compared to 111.5 to 115 EPNdB). The lower noise levels were achieved because of the better climb capability of the airplane with approximately a 240 000-lb takeoff gross weight compared to the climb capability of the airplane with a 325 000-lb takeoff gross weight.

The variation of EPNL along a line 1500 ft to the side of the flight path of the 325 000-lb airplane is shown in figure 56. The 1500-ft sideline distance was also specified in reference 11. The modified nacelles produced about 3-EPNdB reduction in the maximum EPNL (from 109 to 106 EPNdB), which occurred when the airplanes were approximately 1000 ft above the ground and at a distance of 3.5 to 4 n. mi. from brake release. Airplanes with lighter takeoff gross weights would achieve the same noise reduction but at locations closer to the brake-release point.

Initial climb with reduced thrust. – If the thrust can be reduced during the initial climb after liftoff, then lower values of EPNL and larger noise reductions can be achieved at the 3.5-n. mi. point. Takeoff and initial-climb flight paths for an assumed reduced-thrust climb procedure are shown in figure 57. The climb procedure was selected to minimize the EPNL at the 3.5-n. mi. point. The thrust was reduced, at 1500 ft before reaching the 3.5-n. mi. point, to the thrust required to maintain a 6-percent climb gradient (approximately a rate-of-climb of 1000 ft/min). Figure 58 shows the magnitude of the required installed net thrust as a function of takeoff gross weight.

The distance of 1500 ft before the 3.5-n. mi. point, where the thrust was reduced, was selected arbitrarily to allow for a period of time in which the noise at the takeoff-rated-thrust setting could decrease to the value applicable to the reduced-thrust setting. This procedure was required so that the duration-correction factors of figure 37 would be applicable to the EPNLs at the 3.5-n. mi. point with reduced thrust.

Figure 59 compares the EPNL under the initial-climb flight paths for two takeoff weights. For each weight, the variation of EPNL with distance from brake release is shown for the case where the airplane continues to climb with takeoff-rated thrust (along the flight path in figure 52) and for the case where the airplane flies over the 3.5-n. mi. point with a 6-percent climb gradient (along the flight path in figure 57). The noise under the two flight paths is shown to illustrate the difference in the magnitude of the noise reduction obtained at the 3.5-n. mi. point by reducing the climb gradient.

In figure 59(a), reducing the thrust on the 325 000-lb airplane with the modified nacelles reduced the noise at the 3.5-n. mi. point below that produced by the modified airplane climbing with takeoff-rated thrust. However, for the existing airplane, the loss in altitude offset the noise reduction achieved and the EPNL with reduced thrust was approximately the same as that with takeoff-rated thrust. Comparing the two reduced-thrust cases, there was approximately a 5.5-EPNdB reduction due to the modified nacelles at 3.5 n. mi.

For the 325 000-lb airplanes with the existing nacelles, the procedure of minimizing noise at the 3.5-n. mi. point yielded less noise in a region around 3.5 n. mi., but also yielded noise levels in most of the rest of the region under the flight path that were higher by up to 2 EPNdB than those produced by airplanes following the full-thrust flight paths. This result is due to the fact that, for a 6-percent climb gradient, only a small thrust reduction can be made at the 325 000-lb gross weight. Lighter airplanes, however, represent a majority of the flights and require less thrust to maintain a 6-percent climb gradient (see fig. 58). Also, because the slope of the EPNL vs thrust curve is steeper for the modified than for the existing nacelles (see fig. 40), lighter airplanes should be able to produce lower community noise levels than the 325 000-lb airplane.

Figure 59(b) compares EPNLs for airplanes at the gross weights required for a range of 2500 n. mi. Reducing the thrust at these lighter weights reduced the noise of both the existing and the modified airplanes over the 3.5-n. mi. point. The noise from the modified airplane was approximately 9 EPNdB less than that of the existing airplane at 3.5 n. mi. However, as noted in figure 59(a), there was again a crossover in the noise levels and the benefit of reducing the thrust of the existing airplane was only obtained between 3 and 4 n. mi. from brake release. With the modified airplanes, the region of lower noise levels was larger. The basic data available did not permit determination of the location of the crossover between the full-thrust and the reduced-thrust curves for the modified airplane.

Additional information on the noise levels at the 3.5-n. mi. point is given in figure 60 as a function of takeoff gross weight. Although substantially lower noise levels were achieved by the 2500-n. mi.-range airplane with the 6-percent climb gradient, some of this noise benefit could be offset when power is reapplied to expedite the climb to cruise altitude. The results that have been presented are representative of the noise levels that could be obtained. Further application of these techniques would be required to determine optimum climbout procedures for minimum community noise levels around airports.

Reference-day PNLM. – Figure 61 shows reference-day PNLMs under landing approach and initial-climb flight paths. The curves are similar to those presented in figures 50 and 55, except that the numerical values of PNLM are greater than the corresponding values of EPNL and the numerical values of the noise reductions in terms of PNLM are less than in terms of EPNL. At 370 ft under the landing flight path, the nacelle modification on the 240 000-lb airplane reduced the PNLM by 9 PNdB, and on the 180 000-lb airplane by 10 PNdB. At the 3.5-n. mi. point on takeoff, the modified nacelles reduced the PNLM by about 3 PNdB with the 325 000-lb airplane and about 2 PNdB with the airplane flying 2500 n. mi.

Summary of results. – Tables X and XI summarize the noise reductions under the landing and initial-climb flight paths. These results indicate that the nacelle modifications met the noise-reduction design goal of 7 to 10 PNdB during landing approach and did not increase the perceived noisiness during takeoff and initial climb either under the flight path or along a 1500-ft sideline. With the thrust reduced during the initial climb, to that required for a 6-percent climb gradient, larger noise reductions and lower EPNLs would be obtained at the 3.5-n. mi. point.

Airplane Performance

Takeoff and climb performance were determined primarily with data obtained from the test stand evaluations. Cruise performance calculations were based on flight test specific-range data.

General performance assumptions and methods. – All airplane performance calculations assumed standard atmospheric conditions and still air throughout the flight including takeoff, climb, cruise, and descent stages. For flights with a reference payload, a cruise speed of 0.82 mach was assumed. Where the aircraft payload would be limited by the maximum takeoff-gross-weight limit or by the fuel capacity, a cruise speed was assumed at which 99 percent of the maximum specific range would be achieved.

The payload-range data of the existing passenger airplane were based on an operator's weight empty (OWE) of 135 000 pounds for domestic service and 137 490 pounds for international service. The OWEs were increased by 332 pounds for the retrofit airplane to account for the increased weight of the modified nacelles. For both aircraft, the reference payload of 30 175 pounds consisted of 135 passengers with baggage (205 pounds each) and cargo weighing 2500 pounds. Allowance was made for fuel consumed during taxi having a weight of 1000 pounds and fuel consumed during flight maneuvers (before and after enroute flight segments) having a weight of 2000 pounds. The time assumed for these maneuvers was 0.25 hour.

It is current practice to present representative payload-range data utilizing a step-altitude cruise. This is due to the increased airplane range per pound of fuel at higher altitudes for lighter gross weights. The cruise altitudes assumed in this study were 30 000, 35 000, and 40 000 feet.

As an example of the step-altitude cruise procedure, a DC-8-55 with a takeoff gross weight of 325 000 pounds reaches 30 000 feet with a weight of about 313 000 pounds. This altitude is near optimum for this weight. As fuel is burned, the airplane becomes lighter; at a gross weight of 260 000 pounds, performance is improved by climbing to and cruising at 35 000 feet; at a gross weight of 202 000 pounds, the performance is improved by climbing to 40 000 feet. For shorter flights, no steps or only one step may be necessary, depending on the variation in airplane weight.

In actual operations, four-engine commercial jet transports in the U.S.A. use only four traffic-permitted altitudes, having steps of 4000 feet and starting at 29 000 or 31 000 feet, depending on whether the flight heading is east or west. The analytical procedure, using 5000 foot steps, is an approximation of actual operational practice.

For international operating rules, reserve fuel was that fuel required to: (a) fly 10 percent of the block time at the final cruise altitude at a speed at which 99 percent of the maximum specific range would be achieved; plus (b) the fuel required to climb, cruise and descend a total of 200 n. mi. and hold 30 min at 1500 feet. For domestic operating rules, reserve fuel was that fuel required to: (a) fly 1 hour at a speed at which 99 percent of the maximum specific range would be achieved at the final cruise weight and optimum altitude; plus (b) fuel required for a missed approach (2 minutes at takeoff thrust); plus (c) fuel required to climb, cruise (a minimum of 100 n. mi.) and descend over a total distance of 200 n. mi.

Engine performance analysis. – Thrust and fuel flow characteristics used to analyze airplane performance at rated engine powers were based on analysis of the engine performance data obtained in the test stand evaluations discussed previously.

Net thrust was determined by taking the difference between the calculated values of gross thrust and ram drag. Gross thrust is a function of the engine exhaust system performance and depends on the nozzle pressure ratio, nozzle area, the gross thrust coefficient, and ambient pressure. Engine ram drag depends only on engine inlet airflow rate and airplane airspeed.

The results of the static test program (ref. 4) and static tests of the modified flight-nacelle (reported herein) showed that the modified fan exhaust ducts produced the same gross thrust as the existing fan-exhaust ducts at the same value of fan-exhaust pressure ratio. The relationship between fan gross thrust and fan-exhaust pressure ratio for the existing nacelles was therefore used for calculating fan gross thrust for the modified nacelles. The static test stand data were analyzed to develop the relationship between EPR and fan-exhaust pressure ratio. Because the nacelle modification did not affect the primary exhaust system, the existing primary-nozzle gross-thrust characteristics were used for calculating the primary-nozzle gross thrust of the modified nacelle.

Engine manufacturer's data were used to determine the engine airflow rate as a function of the low-pressure rotor speed. The test-stand data showed that the variation of low-pressure rotor speed with EPR was the same for both the existing and modified nacelles. At a given value of rotor speed, the engine referred airflow rate was considered the same for the existing nacelles and the retrofit version of the modified nacelle.

The actual value of airflow, and hence ram drag, varies directly with the inlet total-pressure loss. Analysis of the test-stand data showed that the difference in inlet total-pressure loss between the existing and modified nacelles was equal to 3 percent of the dynamic pressure at the inlet throat. The static test results of reference 4 showed that most of the wakes from the concentric ring and support struts passed through the fan-exhaust ducts. The inlet total-pressure loss affected primarily the fan-exhaust airflow and fan stream thrust, and therefore its small effect on the relationship between the two rotor speeds was neglected. The ram drag calculation included the effect of reducing the fan-exhaust airflow by an amount equivalent to the inlet total-pressure loss.

Calculations of rated thrust using the above methods together with the rated EPR setting curves presented in figure 17 indicated that the rated takeoff, maximum-continuous, and maximum-cruise thrusts would be reduced by 2.5, 2.9, and 3.1 percent, respectively. These thrust reductions would be offset to the extent of the reduction in the drag due to the fan-exhaust flow scrubbing the nacelle afterbody. It was estimated that the longer fan-exhaust ducts would reduce the scrubbing drag approximately 0.4 percent. Since installed net thrust, as defined for airplane performance calculations, includes scrubbing drag as a thrust loss, the reductions in installed net takeoff, maximum-continuous, and maximum-cruise thrust ratings would be 2.1, 2.5, and 2.7 percent, respectively.

The results of the static-test program (ref. 4) showed that the fuel flow rates for the modified nacelle were essentially the same as those for the existing nacelle for the same value of EPR. The relationship between EPR and fuel flow rate used for existing DC-8-55 performance was, therefore, used to calculate fuel flow rates for takeoff and climb of retrofit airplanes.

Airplane performance analysis. – The takeoff-rated thrust reduction of 2.1 percent for an airplane equipped with modified nacelles would result in a decrease in second-segment limiting weights of 2.1 percent. For ambient temperatures up to 84°F at sea level, the resultant loss in second-segment limiting weight would be about 6000 lb for the DC-8-55 airplane. This loss would require that the takeoff flap setting be reduced from 25° to 15° for weights near maximum takeoff weight and that the required field length be consequently increased. This increase in field length requirement is shown in the required takeoff field length curves of figure 62 as the vertical portions of the curves for the modified airplanes. The DC-8-55 field length requirements with existing nacelles are not affected by the second-segment weight limitation at temperatures up to 84°F. The flat tops on the curves for both nacelles correspond to operations at maximum certified takeoff weight of 325 000 lb, and to cruise speeds ranging from high-speed cruise (Mach 0.82) to lower cruise Mach numbers corresponding to long-range cruise.

For long-range flights requiring a large fuel load, the improved cruise fuel consumption of the modified nacelles (as indicated by the improved range factors in figure 45), results in an appreciable reduction in trip fuel requirements and therefore in takeoff weight. When the same flap setting is used for the existing and modified airplanes, figure 62 shows that the takeoff field length for the longer ranges would be less for the modified airplane because the reduction in takeoff weight would more than offset the 2.1 percent reduction in takeoff-rated thrust. For ranges less than approximately 2500 n. mi., where the trip fuel reduction is smaller, the takeoff-rated thrust reduction becomes the predominant effect, and small increases in field length are required.

Climb performance of the DC-8 airplane would not be affected significantly by the nacelle modification. The airplane drag reduction implied by the improved cruise performance is believed to apply only at Mach numbers above approximately 0.6, which occur during the latter portion of the climb. Climb performance during the latter portion of the climb, where the majority of the climb time is spent, would not be appreciably affected by the modification since the drag reduction is approximately equal to the reduction in climb thrust, which is equivalent to rated maximum-continuous thrust for the JT3D-3B engine. At low altitudes and speeds, where the drag advantage may not be present, the thrust-minus-drag margin, and hence, the rate-of-climb is high. Small drag differences during this part of the climb would have a negligible effect on the total time to climb.

No test data were obtained to directly evaluate maximum initial-cruise altitude. However, some estimates were made on the basis of the cruise test data that most nearly approached this condition. The maximum initial-cruise altitude, of the DC-8-55 for all actual gross weights, occurs at a W/δ of 1 100 000 lb. The cruise data at this W/δ and 0.82 Mach number show an apparent drag reduction of 1.2 percent. This reduction in drag is more than offset by the 3.1 percent loss in maximum cruise thrust due to the reduction in the rated maximum-cruise EPR. The resultant loss of 1.9 percent in the thrust-minus-drag margin is estimated to produce a 500-ft decrement in maximum initial-cruise altitude. This decrement would not affect range capability at long-range cruise and would result in less than a 5-n. mi. range reduction at 0.82 Mach cruise.

The measured 3-percent average improvement in specific range would result in an improvement in range capability of about 3.3 percent because of the reduced fuel reserves required. Thus, more fuel would be available for the flight to the destination. The predicted payload-range characteristics, for both domestic and international operating rules, are given in figure 63 for two payloads.

As noted above, the nacelle modification would have essentially no effect on time to climb. Also, the reduction in rated maximum-cruise thrust would not preclude operating the airplane at Mach numbers currently used for either long range or high speed (Mach 0.82) cruise. Therefore, no change in block speed would result from the modification.

Airplane and Engine Operations

Airplane flight envelope. – A study was made to evaluate the effect of the modified engine installation on the structural limitations of the airplane. This study included a comparison between the two configurations with regard to nacelle weight, center of gravity, frontal area, thrust vector, and overall aerodynamic shape. In each of the factors considered, the changes between the two configurations had an insignificant effect on structural loading. It was therefore concluded that the installation of the modified nacelle would not change the flight envelope of speed, altitude, and load-factor from that of the existing airplanes.

Inlet-cowl anti-icing considerations. – It is estimated that the ice protection subsystem described earlier (fig. 4) would require 30 percent more high-pressure engine-bleed airflow than the existing subsystem. The maximum flow rate was calculated for a requirement of 45 minutes of stabilized holding-flight in continuous icing in a 20-mile cloud. The maximum bleed airflow rate was used to size the anti-icing ducting in the inlet concentric-ring and its support struts. The increased engine-bleed flow would require thrust reductions at rated power settings. The required reduction in takeoff-rated thrust would vary from zero at sea level to approximately 0.7 percent at the maximum airfield pressure-altitude certified for takeoff (8000 ft). The climb thrust (maximum-continuous rating) would be reduced by approximately 1.3 percent at a Mach number of 0.59 and a pressure altitude of 15 000 feet; this thrust reduction is a representative average for a typical climb from sea level to initial cruise altitude.

Thrust-reverser considerations. – Although the proposed target fan-exhaust thrust reverser may be less effective than the existing cascade fan-thrust reverser during ground operations, the combined fan/primary reverser effectiveness and, hence, ground-braking performance would be equal to that of other transports in service that are known to have satisfactory performance. No change to the cockpit controls would result from this change.

Maintenance. – Although the maintainability of the nacelle subsystems would remain essentially unchanged, the addition of acoustically treated inlet and fan-exhaust ducts would increase maintenance of the nacelle itself through reducing the access to certain areas of the engine and through the additional maintenance of the acoustical treatment. Line inspection of engine inlet-guide vanes and first-stage fan blades would be somewhat less convenient due to the presence of the ring and support struts. Access to the engine gearbox, accessories, and the aft section of the fan-exhaust ducts would be provided as described previously. No increased maintenance aft of the fan section is expected. The acoustical treatment may require occasional cleaning to remove contaminants as well as repair when damaged by foreign objects. Tests indicating that effective methods can be developed for cleaning porous sheets, as part of sandwich structures, are described in reference 12.

The design of the fan thrust reversers of the modified nacelle is similar to the target reverser currently in airline service both on the Model 62/63 DC-8 and all models of the DC-9 aircraft. Field service experience with both the target and cascade reversers indicates that a reduction in fan thrust-reverser maintenance should be experienced with the proposed design.

CONCLUDING REMARKS

A nacelle modification incorporating acoustically absorptive duct linings for reducing fan-compressor noise, and suitable for retrofit to the existing short-duct nacelles of DC-8 airplanes, has been evaluated for its effect on flyover noise, airplane performance, and operational characteristics.

Flyover Noise Evaluation

Evaluation of the flyover noise test results indicated that reductions in EPNL were obtained under both the landing-approach and initial-climb takeoff flight paths. Under a 3-degree landing flight path at a height of 370 ft, an airplane with modified nacelles, weighing 240 000 lb, would produce 10.5 EPNdB less noise. Larger noise reductions and lower EPNLs would be obtained by airplanes at lower landing weights. The noise reduction would decrease as the distance to the airplane increased.

Under a V_2 + 10 kn initial-climb flight path and at a point 3.5 n. mi. from the start of takeoff roll, the modified nacelles at takeoff-rated power produced 3.5 EPNdB less noise than the existing nacelles on airplanes at the maximum 325 000-lb takeoff gross weight. Airplanes with lower takeoff weights would produce less noise reduction, but also less noise, because of their better climb capability. Along a line 1500 ft to the side of flight path of the 325 000-lb airplane at takeoff-rated thrust, the modified nacelles would produce a 3-EPNdB reduction in the maximum EPNL.

Using a reduced-thrust initial-climb procedure where takeoff-rated power is reduced, at 1500 ft before the 3.5-n. mi. point to the thrust required to maintain a 6-percent climb gradient, the modified nacelles on an airplane weighing 325 000 lb would reduce the EPNL by 5.5 EPNdB at the 3.5-n. mi. point. Lighter-weight airplanes would produce larger noise reductions and less noise over the 3.5-n. mi. point than the airplane weighing 325 000 lb.

Predictions of noise levels under landing approach and takeoff flight paths were based on sound pressure level measurements at a distance of 150 ft around an engine test stand. Comparison with flyover noise measurements indicated good agreement in terms of the level and the spectrum of the one-third octave-band sound pressure levels, at the instant of maximum perceived noise level, for both the existing and the modified nacelles. Reasonably good agreement was also obtained between the measured and the predicted maximum perceived noise levels.

Nacelle and Airplane Performance

Tests on the engine test stand, performed prior to the flight tests, indicated that the reduction in installed thrust at takeoff-rated power would be 2.1 percent. No engine surges were experienced during operations from idle to takeoff thrust in simulated 90-degree crosswinds up to 35 knots. Measurements of fan disk and blade stresses indicated that the modification increased the stresses in the second-stage fan blades such that a 100-rpm reduction in the low-pressure rotor speed limit was established for the flight test program. This increase in fan-blade stress could be eliminated in the development of a retrofit nacelle.

Analysis of the cruise performance data obtained in the flight test program indicated that the maximum range capability of a DC-8-55 airplane with a full passenger payload would be increased approximately 3.3 percent by the modified nacelles. Takeoff field-length requirements would be increased slightly for operations at ranges less than approximately 2500 n. mi. and would be decreased for greater ranges. The maximum initial-cruise-altitude capability would be reduced approximately 500 ft. Climb and cruise calculations indicated that block speeds would not be appreciably affected by the modified nacelles.

Operational Changes

Operational changes predicted for a retrofitted airplane would involve the increased inlet-cowl ice-protection requirements and increased nacelle maintenance due to the acoustical treatment. Reductions in rated engine thrusts during anti-icing operation, due to the increased engine-bleed airflows, would be required during some operations.

The simpler target fan-thrust reversers should result in less thrust-reverser maintenance. Based on flight tests, no change was indicated for the engine restarting flight conditions and no changes are anticipated in flight crew operation of retrofitted airplanes.

Douglas Aircraft Company
McDonnell Douglas Corporation
Long Beach, California, November 1969

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APPENDIX A

FAR-FIELD SPL DATA FOR EXISTING AND MODIFIED NACELLES

Tables A-1 and A-2 present average 1/3-octave-band SPLs for the existing and the modified nacelle configurations. SPLs are listed for the 24 bands with center frequencies between 50 and 10 000 Hz and at the 14 microphone locations, along the 150-ft arc centered at the primary exhaust nozzle, at azimuths from 15 to 157 deg relative to the engine inlet. The acoustic power level (PWL in dB re 10^{-13} watts) is listed for each 1/3-octave band. The overall PWL (50 to 10 000 Hz bandwidth) is also listed.

Each table contains nine parts, one for each of the engine power settings for which data were obtained. As explained in reference 4, the engine power settings for the acoustical tests were determined by the referred low-pressure rotor speed which ranged from a nominal 2200 to a nominal 6300 rpm. Average referred-net-thrust, low-pressure rotor speed and engine pressure ratio, as well as calculated values of primary jet-exhaust velocity, are listed at the bottom of each table.

TABLE A-1. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH EXISTING NACELLE

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 151, 152, AND 153 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	67.0	70.6	69.4	70.8	71.0	71.0	71.2	71.8	71.5	71.9	73.0	73.7	74.2	75.6	123.4
A	63	69.6	67.3	68.6	68.3	70.7	69.9	70.3	71.1	71.4	71.7	71.7	72.3	72.4	73.3	122.3
N	80	71.0	68.1	68.7	70.2	70.2	70.2	70.8	70.5	70.0	70.4	70.9	71.7	72.3	72.7	122.1
D	100	68.7	72.4	71.7	71.6	74.0	72.4	71.5	74.0	71.9	71.7	72.6	74.1	74.4	73.5	124.2
	125	70.5	70.8	70.0	70.4	70.5	70.6	72.1	73.1	72.8	73.4	75.0	76.3	76.1	73.5	124.3
C	160	70.8	71.2	72.5	71.5	70.7	70.9	72.7	73.9	73.6	73.9	74.0	75.1	76.0	73.6	124.5
E	200	70.8	73.5	72.9	72.9	73.0	72.7	70.6	71.5	72.5	72.6	73.4	73.8	73.9	72.8	124.1
N	250	72.0	73.2	71.5	70.5	70.1	70.3	70.8	72.9	73.1	74.5	73.0	74.6	72.0	71.4	123.7
T	315	73.1	73.3	71.7	70.9	71.7	71.9	71.5	73.1	73.9	74.4	73.7	74.2	72.6	71.5	124.2
E	400	80.7	83.1	80.5	77.2	81.3	74.0	77.1	76.7	79.1	81.5	80.0	81.7	83.5	81.3	131.4
R	500	72.6	72.5	71.2	70.6	69.5	70.2	69.9	72.2	73.3	74.1	74.8	72.0	69.1	67.6	123.3
	630	84.0	83.3	79.8	76.8	75.0	72.8	72.5	72.1	72.4	75.5	76.8	75.4	71.3	69.4	128.3
F	800	81.2	78.4	74.1	72.9	70.4	69.2	69.6	69.8	70.3	75.2	76.4	75.7	69.6	68.4	125.4
R	1000	79.9	76.6	74.4	72.4	69.1	69.1	71.5	73.6	72.2	76.5	80.0	76.1	69.0	70.6	126.1
E	1250	80.5	80.2	81.6	79.9	77.3	75.9	76.4	79.9	75.3	78.4	82.5	79.8	73.4	72.1	130.2
Q	1600	80.3	79.6	79.9	81.2	79.6	77.2	75.5	77.9	77.5	77.4	77.3	75.0	70.2	69.2	129.5
U	2000	86.3	87.2	85.2	82.3	78.8	76.8	76.8	78.1	79.9	80.5	81.3	77.3	72.1	71.7	132.5
E	2500	89.6	91.3	92.6	90.0	83.7	81.9	85.2	83.2	86.1	85.9	88.1	84.6	78.5	77.0	138.4
N	3150	82.4	83.8	82.4	79.9	77.3	75.6	77.3	82.5	80.8	81.1	82.2	78.2	73.4	70.6	131.6
C	4000	83.2	82.6	82.5	80.1	79.3	77.5	81.0	84.9	83.5	84.6	83.9	80.2	75.8	73.4	133.4
Y	5000	81.0	82.2	82.3	79.1	76.9	74.3	77.7	80.0	81.2	81.1	82.1	78.4	73.8	70.7	131.0
,	6300	79.9	78.4	78.6	77.1	74.6	72.5	75.3	78.5	79.2	78.9	81.5	75.6	70.6	68.3	128.9
H	8000	76.8	76.8	76.5	74.8	72.6	70.6	73.9	76.0	78.7	77.7	78.6	72.4	68.9	65.9	126.9
Z	10000	74.0	73.3	73.1	71.4	69.3	69.0	72.9	74.4	75.9	76.5	75.6	70.8	66.8	62.9	124.6

AVERAGE NET REFERRED THRUST, FN/DELTA = 1364.6 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 2198.2 RPM
AVERAGE JET EXHAUST VELOCITY = 348.8 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.04

TOTAL PWL= 143.5

TABLE A-1. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH EXISTING NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 151, 152, AND 153 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	74.8	77.0	76.6	77.8	78.4	79.2	80.4	80.9	81.3	82.6	83.1	84.3	85.2	85.9	132.9
A	63	80.6	78.4	79.1	79.0	79.9	80.4	81.5	82.4	82.5	83.5	84.0	85.3	86.0	85.7	133.9
N	80	82.8	79.4	80.1	81.6	82.6	83.1	82.9	82.5	82.3	83.5	84.9	86.2	86.4	84.7	134.8
D	100	82.5	80.5	82.3	82.7	83.9	83.1	82.0	82.1	82.1	82.9	84.3	86.5	86.6	84.1	134.9
	125	79.3	79.9	80.5	81.7	81.6	81.1	82.2	82.6	82.2	83.2	84.9	86.5	86.2	82.9	134.3
C	160	79.4	80.4	81.8	80.9	79.9	80.7	81.5	82.6	82.6	83.4	84.3	85.7	85.4	81.3	133.8
E	200	79.1	80.9	79.8	78.7	80.0	79.7	79.2	80.4	81.0	80.9	81.8	82.7	82.6	79.9	132.0
N	250	79.9	79.6	78.9	79.9	78.5	80.0	79.5	81.5	82.0	83.0	82.7	81.2	80.8	79.7	132.2
T	315	80.0	78.9	78.7	78.9	79.4	80.2	80.5	81.6	82.2	82.7	82.6	81.0	79.6	79.1	132.2
E	400	79.3	79.9	78.6	79.0	79.3	79.8	80.3	82.2	83.0	83.7	81.6	80.7	78.3	78.1	132.3
R	500	78.2	78.8	77.5	77.1	76.6	78.2	78.3	79.9	81.1	82.1	81.8	80.0	77.3	75.3	130.7
	630	79.1	78.8	76.7	76.5	75.0	75.9	77.1	78.0	78.3	80.5	80.8	78.9	76.5	74.4	129.4
F	800	80.1	79.1	76.7	76.0	74.3	74.1	75.0	75.8	76.2	79.9	79.3	77.0	74.4	73.0	128.3
R	1000	83.7	88.8	85.0	84.1	80.3	78.4	76.3	78.6	78.8	82.5	81.6	78.1	75.3	74.7	133.8
E	1250	85.0	83.8	82.9	81.9	80.5	79.2	80.5	82.3	82.5	85.1	83.1	80.4	76.2	75.4	133.4
Q	1600	86.2	86.0	86.6	84.6	84.0	82.2	84.1	86.7	84.9	85.7	84.0	80.2	78.0	76.7	135.9
U	2000	94.0	95.1	97.9	94.1	93.1	90.1	90.2	98.3	93.1	95.7	92.2	89.5	87.9	85.5	145.4
E	2500	92.2	92.1	91.7	89.3	87.7	85.9	85.6	88.3	88.2	89.3	88.6	82.8	79.7	76.9	139.8
N	3150	91.7	91.1	90.3	89.9	88.4	86.1	86.5	88.6	88.9	89.6	89.0	83.2	79.9	76.9	139.8
C	4000	95.6	96.0	96.3	95.8	93.6	92.3	96.0	98.9	99.9	98.4	95.7	91.0	87.4	85.0	147.6
Y	5000	91.9	91.2	90.8	90.0	88.2	87.9	91.4	91.5	92.0	92.2	90.5	86.8	82.7	79.9	141.7
,	6300	92.1	93.8	92.1	91.9	91.6	90.0	93.0	93.5	94.2	93.1	92.7	88.0	83.6	80.8	143.5
H	8000	89.5	90.4	89.5	87.4	86.5	86.3	89.0	90.5	92.5	89.9	89.6	83.4	80.0	77.7	140.3
Z	10000	87.1	87.1	86.7	86.0	84.0	85.1	88.3	89.0	89.6	89.1	86.4	82.1	78.4	73.6	138.3

AVERAGE NET REFERRED THRUST, FN/DELTA = 3833.7 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 3551.1 RPM
AVERAGE JET EXHAUST VELOCITY = 583.7 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.11

TOTAL PWL= 153.0

TABLE A-1. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH EXISTING NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 151, 152 AND 153 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	78.7	80.0	80.5	81.4	82.3	82.9	84.5	85.3	86.0	87.6	89.0	91.2	92.5	92.6	138.4
A	63	83.0	81.7	81.8	81.8	83.5	84.6	86.6	87.7	87.5	89.0	90.6	93.1	94.2	93.6	140.0
N	80	87.8	84.1	84.3	86.1	86.5	87.6	87.6	88.2	88.2	89.8	91.8	94.0	94.7	92.0	140.9
D	100	85.6	85.6	87.1	87.7	89.0	87.9	87.2	87.3	87.7	89.6	92.4	95.3	95.0	91.8	141.4
	125	83.9	84.8	85.6	86.7	86.7	85.7	86.4	87.6	87.8	89.8	92.1	94.6	93.6	90.0	140.5
C	160	84.6	85.1	86.6	86.1	85.3	85.6	86.4	87.7	87.7	89.0	90.9	93.4	92.1	88.7	139.8
E	200	84.6	85.9	85.1	84.5	85.4	84.8	86.2	86.8	87.1	87.9	89.3	91.3	90.8	88.0	138.7
N	250	85.1	83.8	84.4	83.8	84.1	84.9	85.2	86.8	87.6	88.3	88.7	89.0	88.4	86.5	137.9
T	315	84.4	83.7	83.8	84.1	84.7	85.1	85.7	86.9	87.6	88.2	88.6	88.1	86.1	85.3	137.7
E	400	83.4	83.9	83.1	83.4	83.9	84.3	85.2	87.2	87.6	88.4	87.2	87.2	84.3	84.0	137.2
R	500	81.6	82.3	81.1	81.4	81.2	82.9	83.5	85.0	85.6	87.0	86.6	86.0	82.9	81.1	135.5
	630	81.6	81.1	79.7	79.5	79.1	80.1	81.6	82.0	82.1	84.5	85.1	84.1	81.7	79.2	133.4
F	800	81.4	80.0	78.3	78.1	77.1	77.7	79.4	79.7	79.7	82.9	83.3	81.9	79.0	77.3	131.5
R	1000	84.0	84.5	84.1	84.9	83.4	82.1	80.5	81.9	82.0	84.4	83.8	81.4	78.6	78.2	134.3
E	1250	90.1	90.2	89.3	87.8	86.2	84.9	86.3	87.5	86.2	88.4	84.7	83.0	79.9	79.0	138.3
Q	1600	89.5	87.3	87.7	87.4	86.2	86.9	88.4	92.1	90.4	91.1	86.2	84.0	81.6	78.8	139.9
U	2000	92.9	92.9	95.1	92.1	90.2	92.3	94.8	92.6	98.3	96.9	92.6	91.5	86.6	85.4	145.3
E	2500	97.3	100.2	104.0	101.9	100.8	98.6	102.0	99.1	104.6	103.5	99.2	98.2	93.9	91.9	152.6
N	3150	93.6	93.8	93.4	93.8	90.6	90.0	90.9	92.4	92.4	92.6	89.6	86.8	84.5	81.4	143.0
C	4000	93.8	94.4	94.7	93.5	91.2	92.8	94.8	97.1	96.7	95.3	91.9	88.6	86.8	83.6	145.5
Y	5000	99.1	98.9	97.9	97.0	95.3	96.5	99.1	101.9	102.1	101.3	98.1	94.1	91.7	87.5	150.2
,	6300	93.4	94.1	93.9	93.4	92.5	92.9	94.5	96.3	96.6	95.3	92.8	89.2	85.7	83.9	145.3
H	8000	93.3	95.8	94.7	93.6	92.9	92.3	94.7	95.5	97.8	95.7	94.0	88.8	85.7	82.3	145.7
Z	10000	91.0	93.2	92.4	90.8	89.5	91.0	93.1	93.3	94.4	93.7	89.3	85.8	83.3	79.0	143.2

AVERAGE NET REFERRED THRUST, FN/DELTA = 6088.2 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 4294.1 RPM
AVERAGE JET EXHAUST VELOCITY = 781.4 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.20

TOTAL PWL= 157.7

TABLE A-1. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH EXISTING NACELLE-Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 151, 152, AND 153 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

BAND CENTER FREQUENCY, HZ	ANGLES FROM ENGINE INLET CENTERLINE, DEGREES 15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
50	80.7	81.4	82.0	82.1	83.9	84.6	85.9	87.2	88.5	89.6	91.3	94.1	96.0	96.3	141.1
63	83.9	82.5	83.3	83.4	84.6	85.9	88.7	89.4	89.9	91.3	93.8	96.6	97.6	96.2	142.7
80	88.7	85.2	85.4	87.0	88.3	89.1	89.8	90.5	91.0	92.4	95.4	98.0	98.6	96.0	144.0
100	87.7	87.6	89.2	89.7	90.9	89.6	89.2	89.9	91.1	92.7	95.8	99.1	98.4	95.1	144.4
125	86.0	86.7	87.1	88.2	88.6	87.7	88.4	89.7	91.0	92.4	95.5	97.9	96.8	93.2	143.3
160	86.7	87.2	88.3	87.9	87.2	87.9	88.6	89.9	90.6	91.7	94.3	97.0	95.4	91.7	142.6
200	86.7	87.7	86.9	86.0	87.3	87.0	87.9	89.1	90.1	90.5	92.5	94.8	93.6	90.6	141.3
250	87.3	85.7	85.6	85.7	86.2	87.0	87.6	89.1	90.8	91.0	92.1	92.7	92.0	89.4	140.7
315	86.3	85.7	85.6	85.8	86.5	87.2	88.1	89.3	90.4	90.7	91.3	91.2	88.9	88.4	140.2
400	85.5	85.7	85.2	85.5	86.2	86.4	87.6	89.3	90.2	90.8	90.1	89.9	86.7	86.5	139.6
500	83.7	84.5	83.3	83.4	83.7	85.0	85.9	86.9	88.4	89.6	89.3	88.7	85.5	83.5	138.0
630	83.1	83.0	81.7	81.4	81.4	82.8	84.1	84.6	85.3	87.1	87.7	86.7	84.2	81.9	135.9
800	83.3	81.8	80.1	80.1	79.4	80.2	82.1	82.1	82.9	85.0	85.7	84.5	81.5	79.5	133.9
1000	85.2	85.4	84.7	86.2	85.3	84.2	82.7	84.3	84.7	87.2	85.9	83.6	80.7	80.2	136.2
1250	90.0	91.2	89.5	88.6	87.6	86.8	86.5	88.5	87.9	89.4	86.4	84.6	81.3	81.1	139.3
1600	90.5	89.1	89.0	88.2	87.1	88.2	89.4	92.6	91.7	92.8	87.3	85.5	82.6	80.6	141.0
2000	91.6	90.5	90.1	88.5	87.9	89.4	91.1	92.0	92.4	94.5	88.3	85.8	83.2	80.3	141.9
2500	100.4	104.5	103.0	99.7	99.2	100.1	107.0	104.1	106.2	105.9	99.5	95.9	95.0	91.9	154.7
3150	93.5	94.6	93.5	92.2	91.3	91.3	95.5	94.9	95.4	94.6	92.5	89.5	87.4	84.1	144.8
4000	94.2	94.2	94.1	93.2	92.0	91.7	93.9	95.7	94.5	93.8	91.1	88.0	85.1	81.9	144.5
5000	98.1	97.7	97.1	96.7	96.1	97.5	101.3	102.2	103.1	101.3	96.8	95.3	90.8	87.8	150.8
6300	93.4	93.7	93.6	92.5	91.6	92.9	94.7	95.8	96.0	95.2	92.1	89.5	85.6	83.0	145.0
8000	94.6	95.2	95.3	94.7	93.0	94.0	97.0	98.0	99.8	97.5	93.9	89.2	87.3	83.9	147.2
10000	91.6	92.5	92.1	91.2	89.8	92.3	94.9	90.2	96.7	95.8	90.6	87.6	84.9	80.1	144.2

AVERAGE NET REFERRED THRUST, FN/DELTA = 7237.0 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED, N1/VTHETA = 4596.0 RPM
AVERAGE JET EXHAUST VELOCITY = 861.4 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.24

TOTAL PWL = 159.1

TABLE A-1. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH EXISTING NACELLE–Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 151, 152, AND 153 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

BAND CENTER FREQUENCY, HZ	ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
	15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
50	82.1	82.9	83.5	83.8	85.0	85.7	87.1	88.3	89.8	91.5	94.0	96.9	99.2	98.4	143.4
63	84.9	83.8	83.9	84.3	85.7	87.9	90.3	90.7	91.0	93.3	96.4	99.7	100.9	99.4	145.3
80	89.8	86.1	87.0	88.5	89.2	90.3	91.4	92.2	92.7	94.9	98.2	101.3	102.3	99.2	146.7
100	89.3	89.3	91.0	91.3	92.4	91.3	91.0	92.0	93.1	95.5	99.1	102.4	102.0	98.4	147.3
125	88.1	88.1	88.9	90.2	90.6	89.6	90.7	92.2	93.1	95.5	98.9	101.8	100.8	97.2	146.5
160	89.1	89.0	90.3	89.9	89.3	90.0	91.0	92.2	92.8	94.5	97.7	100.8	98.9	95.4	145.7
200	88.9	89.2	88.9	87.9	89.0	89.1	90.1	91.2	92.1	93.3	95.8	98.4	96.6	93.6	144.0
250	89.9	87.6	88.0	87.8	88.4	89.4	90.1	91.7	92.9	93.8	94.9	96.2	94.7	91.9	143.3
315	88.4	87.7	88.1	88.1	88.5	89.2	90.3	91.6	92.6	93.5	94.3	94.7	92.0	91.4	142.8
400	87.5	87.8	87.4	87.4	88.3	88.6	89.8	91.6	92.4	93.2	92.9	93.0	89.6	89.1	142.0
500	85.7	86.3	85.3	85.8	86.1	87.3	88.1	89.5	90.2	91.9	91.9	91.5	87.9	86.0	140.3
630	85.0	84.8	84.0	83.8	84.1	85.4	86.2	87.2	87.3	89.8	90.4	89.3	86.5	83.6	138.3
800	84.5	83.6	82.2	81.8	82.1	82.6	83.9	84.3	84.8	87.6	88.3	86.6	83.5	81.6	136.1
1000	86.2	85.5	84.4	85.6	83.7	83.4	83.7	85.6	85.8	88.1	87.5	85.1	82.2	81.0	136.7
1250	88.3	91.6	89.9	89.2	87.0	86.9	89.3	90.3	91.3	94.4	87.6	86.5	85.2	82.2	141.1
1600	89.6	87.3	87.1	86.8	86.6	87.0	88.7	91.2	91.0	91.1	87.3	85.4	83.1	80.5	139.9
2000	93.3	90.1	89.3	89.1	88.4	90.0	91.9	92.5	92.2	92.9	89.3	86.7	84.3	81.4	142.1
2500	102.9	102.6	100.5	101.8	97.5	100.3	99.8	102.8	106.9	105.9	101.3	99.0	96.7	94.5	153.7
3150	101.2	101.4	99.1	99.5	95.6	97.8	98.7	99.6	98.8	104.0	99.6	97.0	94.5	90.4	150.8
4000	94.0	93.9	93.2	92.8	91.4	91.9	94.2	95.9	95.0	94.4	91.1	88.8	85.9	82.9	144.6
5000	96.9	96.9	96.1	95.5	94.5	98.9	101.5	101.7	100.4	100.2	95.8	93.2	89.7	87.4	150.0
6300	95.3	96.3	95.8	95.0	94.2	95.8	96.9	98.4	97.5	97.8	95.2	92.4	88.1	86.1	147.4
8000	94.0	96.1	94.5	93.9	93.7	97.2	98.3	98.4	100.6	98.8	95.3	90.9	87.8	85.4	148.2
10000	91.3	92.6	91.8	91.4	90.3	93.7	95.5	96.7	96.8	96.8	92.7	89.1	86.3	81.8	145.4

AVERAGE NET REFERRED THRUST, FN/DELTA = 8640.7 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 4899.7 RPM
AVERAGE JET EXHAUST VELOCITY = 961.0 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.30

TOTAL PWL= 160.1

TABLE A-1. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH EXISTING NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 151, 152, AND 153 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	95.1	85.0	86.0	85.9	86.5	87.5	89.6	91.0	92.2	95.0	98.5	101.6	104.3	103.3	147.9
A	63	86.9	85.9	86.2	86.5	87.3	89.2	92.1	93.8	94.3	97.4	101.0	104.4	105.9	103.5	149.5
N	80	91.2	87.7	89.3	90.1	90.8	92.2	94.6	95.3	96.1	99.5	103.4	106.5	107.1	103.7	151.2
D	100	91.5	90.9	93.0	93.1	93.9	93.9	94.5	96.0	97.2	100.0	104.5	108.3	107.5	103.1	152.1
	125	91.7	90.9	91.9	92.8	92.8	92.6	94.4	96.1	97.1	100.0	104.6	108.2	106.1	102.2	151.8
C	160	93.2	92.3	93.7	93.7	93.2	93.9	94.3	96.2	97.1	99.4	103.7	106.7	104.5	100.7	150.8
E	200	93.2	92.6	92.1	91.5	92.3	92.7	94.0	95.5	96.5	98.2	101.5	104.3	101.8	98.1	149.0
N	250	93.2	91.3	91.6	91.6	91.8	92.7	93.7	95.9	96.9	98.3	100.2	101.9	99.8	95.9	147.9
T	315	92.1	91.6	91.7	91.5	91.8	92.7	93.9	95.7	96.8	98.3	99.6	99.8	96.8	94.7	147.1
E	400	90.7	91.0	90.7	90.6	91.2	91.5	93.1	94.9	96.1	97.4	98.2	98.2	93.5	92.6	146.0
R	500	88.9	89.3	88.5	88.5	88.6	89.9	91.3	93.0	93.3	96.0	96.6	96.0	91.5	88.5	144.0
	630	87.9	88.2	87.0	86.8	86.8	88.0	89.4	90.2	90.7	94.1	94.9	93.1	90.3	86.8	141.9
F	800	88.6	86.7	86.0	85.0	84.7	85.6	87.0	87.8	88.5	92.0	92.6	90.8	87.4	84.9	139.8
R	1000	91.1	87.2	88.2	87.2	87.9	88.4	87.8	89.8	89.9	92.4	92.3	88.8	85.9	83.2	140.7
E	1250	91.7	92.4	93.3	89.8	91.0	91.9	92.8	93.9	92.7	94.2	91.6	88.7	86.0	83.0	143.5
Q	1600	91.0	91.2	90.6	90.7	89.7	92.1	91.6	93.3	93.1	93.1	90.6	88.3	84.6	81.8	142.8
U	2000	96.9	93.7	91.6	90.6	90.4	92.2	93.1	94.2	94.8	94.2	92.0	89.4	86.0	82.4	144.2
E	2500	100.0	100.2	98.8	96.6	98.2	100.7	103.7	105.9	103.4	106.7	100.1	96.2	97.2	88.2	153.6
N	3150	104.3	108.4	104.8	103.7	103.9	105.3	105.1	107.8	104.5	107.8	102.6	99.9	99.8	95.3	156.6
C	4000	95.6	95.2	94.7	94.1	93.3	94.4	96.7	97.3	96.5	96.7	94.7	92.5	88.7	83.9	146.6
Y	5000	98.0	96.5	95.7	96.0	95.7	98.7	99.9	104.9	100.1	102.0	95.7	94.2	90.9	81.7	150.8
,	6300	98.6	100.0	98.6	98.9	98.2	100.6	101.8	104.9	104.4	103.6	99.7	96.9	92.9	83.6	152.7
H	8000	95.0	95.9	95.5	95.0	94.2	97.1	99.4	101.6	100.5	99.9	96.3	92.0	89.8	81.2	149.2
Z	10000	94.2	95.4	95.7	94.4	94.3	96.5	98.3	100.6	99.1	99.1	95.6	92.0	88.9	79.4	148.4

AVERAGE NET REFERRED THRUST, FN/DELTA = 10906.4 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 5343.1 RPM
AVERAGE JET EXHAUST VELOCITY = 1119.6 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.41

TOTAL PWL= 163.5

TABLE A-1. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH EXISTING NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 151, 152, AND 153 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	95.9	86.2	87.1	87.2	88.3	89.4	90.7	92.4	93.9	97.1	100.9	104.8	107.3	106.7	150.7
A	63	87.7	87.6	87.5	88.3	89.4	91.5	93.8	95.2	96.5	100.3	104.6	107.6	109.5	107.5	152.8
N	80	91.1	89.0	90.7	91.8	93.6	94.6	95.8	96.8	97.9	101.9	106.9	110.3	110.9	107.1	154.5
D	100	93.3	94.5	94.0	94.7	95.6	95.6	96.6	98.3	99.8	103.1	108.7	112.8	111.4	107.6	156.1
	125	93.9	93.0	93.8	95.0	95.5	94.8	96.8	98.5	100.2	103.9	109.1	113.0	110.2	107.6	156.1
C	160	96.1	94.9	96.3	96.0	95.4	95.6	97.4	99.0	100.5	102.8	108.8	112.2	109.1	106.5	155.5
E	200	96.3	95.3	94.7	94.1	94.9	95.3	96.6	98.6	100.1	102.1	106.5	110.2	107.8	104.3	153.8
N	250	95.7	93.9	94.3	94.2	94.7	95.3	96.7	98.7	100.2	101.8	104.9	107.1	105.2	100.9	152.1
T	315	94.3	94.0	94.3	94.2	94.5	95.4	96.9	98.7	100.3	101.8	103.8	104.5	101.7	99.7	150.9
E	400	92.8	93.1	93.1	93.4	94.1	94.4	95.6	97.7	99.2	100.6	102.1	102.3	97.9	97.0	149.3
R	500	91.4	91.7	91.1	91.3	91.7	92.9	94.1	95.7	96.7	98.9	100.7	99.8	94.9	93.0	147.3
	630	90.2	90.1	89.6	89.3	89.6	90.8	91.9	92.9	93.2	97.0	98.6	97.0	93.4	90.7	145.0
F	800	90.3	88.5	87.6	87.5	88.0	88.0	89.3	90.0	91.1	94.4	95.8	93.6	90.3	88.6	142.5
R	1000	90.7	87.9	88.2	87.7	87.6	88.8	89.4	91.0	92.5	93.7	94.2	90.9	87.7	86.9	142.0
E	1250	91.9	91.5	92.7	90.5	92.8	92.6	94.8	96.0	97.6	95.7	92.7	90.5	87.7	87.6	145.3
Q	1600	93.9	94.4	94.6	94.1	94.1	94.2	93.6	96.8	96.0	95.6	93.4	90.8	88.2	86.0	145.8
U	2000	99.4	96.5	95.0	93.5	93.2	94.3	95.0	96.2	96.4	97.7	95.3	91.8	88.6	86.0	146.7
E	2500	99.0	98.4	99.0	96.0	97.0	99.1	101.4	105.6	101.7	100.3	97.6	95.7	93.6	90.0	151.6
N	3150	104.9	109.6	109.7	102.2	104.6	109.2	106.3	117.8	111.5	106.5	105.5	105.4	103.7	99.3	161.6
C	4000	98.6	97.5	96.9	95.3	95.2	96.5	100.0	100.8	99.1	100.1	98.9	96.5	92.8	89.1	149.5
Y	5000	98.4	97.9	97.0	96.2	95.7	97.7	99.3	101.7	98.9	98.8	95.8	94.0	90.8	88.3	149.4
,	6300	98.8	101.5	100.7	98.4	98.1	101.2	103.7	109.7	103.5	104.7	101.4	98.8	94.6	93.6	154.6
H	8000	95.0	96.3	95.8	93.8	94.3	98.3	99.3	102.3	100.6	99.2	97.3	93.6	90.3	87.4	149.5
Z	10000	94.5	94.7	95.2	93.7	93.5	100.0	101.1	105.2	101.3	100.1	96.6	94.0	90.8	86.8	150.9

AVERAGE NET REFERRED THRUST, FN/DELTA = 13069.3 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 5698.0 RPM
AVERAGE JET EXHAUST VELOCITY = 1259.0 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.52

TOTAL PWL= 166.9

TABLE A-1. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH EXISTING NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 151, 152, AND 153 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	97.8	87.5	88.2	88.5	89.8	90.6	92.4	94.0	95.6	99.0	103.4	107.4	110.1	108.5	153.0
A	63	89.7	88.8	89.1	89.9	91.1	93.2	95.7	96.3	98.2	102.1	106.8	110.7	112.3	109.2	155.3
N	80	92.6	90.7	92.2	93.3	94.3	95.8	97.1	98.2	99.6	104.4	109.6	113.3	113.7	108.9	157.1
D	100	95.0	93.9	95.1	95.8	97.3	97.7	99.1	100.5	101.6	105.6	112.1	115.9	114.4	110.0	159.0
	125	96.1	95.3	96.3	96.8	97.0	97.0	99.2	101.1	102.3	106.4	113.0	116.9	113.7	110.3	159.6
C	160	99.0	97.3	98.6	97.8	97.9	98.0	99.9	101.8	102.9	106.1	113.2	116.7	113.3	110.1	159.5
E	200	99.4	97.7	97.1	96.3	97.5	98.1	99.4	101.3	103.0	106.1	111.2	115.2	112.6	107.8	158.2
N	250	97.8	96.5	96.9	96.8	97.4	98.1	99.4	101.2	102.6	105.4	108.9	112.3	110.4	104.5	156.1
T	315	96.6	96.8	96.9	96.9	97.1	98.0	99.7	101.2	103.3	105.1	107.6	109.2	106.6	103.2	154.5
E	400	95.4	95.4	95.7	95.7	96.7	96.9	98.4	100.3	101.8	104.2	105.8	106.6	102.9	99.8	152.7
R	500	93.7	94.2	93.7	94.1	94.5	95.3	96.5	98.2	99.2	103.1	104.0	103.8	98.9	95.3	150.5
	630	92.5	92.9	92.5	92.3	92.4	93.6	94.2	95.1	96.3	101.2	102.1	100.2	96.5	92.9	148.2
F	800	92.6	91.5	90.8	90.6	90.4	91.1	91.6	92.8	94.2	98.0	99.0	96.4	93.3	90.6	145.5
R	1000	92.4	91.1	90.1	90.5	90.5	90.9	91.5	93.3	94.7	97.9	96.7	93.8	90.8	88.4	144.7
E	1250	94.8	95.5	93.9	94.0	96.9	94.1	97.7	98.6	98.9	99.4	95.5	93.2	90.9	88.0	147.9
Q	1600	96.5	97.0	96.9	96.4	95.5	95.3	96.7	98.5	98.8	100.7	96.1	93.9	91.0	88.2	148.4
U	2000	98.6	98.0	98.4	96.6	96.3	96.4	97.1	97.9	98.2	101.9	97.6	94.5	91.8	87.9	149.1
E	2500	99.1	98.9	97.5	97.3	97.3	99.4	102.1	101.8	100.4	102.3	97.9	95.4	93.0	90.4	151.0
N	3150	106.9	105.7	106.0	104.9	103.3	109.6	109.6	115.6	112.2	109.9	107.1	103.5	101.6	102.8	161.0
C	4000	100.1	99.2	99.1	98.2	97.8	100.2	101.3	102.4	103.3	104.0	102.3	99.6	96.0	92.3	152.3
Y	5000	97.6	97.7	97.5	96.9	96.2	98.3	99.3	100.1	98.8	101.4	96.7	95.0	91.6	87.9	149.6
,	6300	99.1	101.5	99.8	98.7	98.3	102.8	104.9	106.8	104.7	104.1	100.9	98.0	94.4	92.3	154.1
H	8000	95.5	96.0	95.7	94.4	95.1	98.3	100.0	100.3	100.3	101.3	98.4	94.9	91.8	88.2	149.7
Z	10000	94.4	94.8	94.6	94.2	94.3	101.4	101.8	103.3	101.3	101.8	97.4	94.2	91.4	86.9	151.0

AVERAGE NET REFERRED THRUST, FN/DELTA = 15070.4 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 5994.1 RPM
AVERAGE JET EXHAUST VELOCITY = 1387.0 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.64

TOTAL PWL= 168.9

TABLE A-1. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH EXISTING NACELLE - Concluded

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 151, 152, AND 153 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

	ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
BAND CENTER FREQUENCY, HZ	15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
50	98.3	88.5	89.5	89.5	90.7	91.6	93.8	95.8	97.1	101.5	106.8	110.4	113.6	111.8	156.1
63	91.3	89.8	90.5	91.4	92.4	94.4	96.5	97.6	100.0	104.4	109.6	113.6	115.6	112.0	158.1
80	94.1	92.0	93.8	94.7	96.0	97.2	98.6	99.8	101.5	107.0	112.9	116.5	117.0	112.3	160.2
100	97.0	95.5	96.6	96.9	98.8	99.1	100.5	102.0	103.7	108.8	115.6	119.0	117.4	113.6	162.1
125	97.8	97.4	97.7	98.1	98.5	98.9	101.4	103.2	104.7	110.5	117.2	120.5	116.8	114.3	163.2
160	101.4	99.4	100.5	99.7	100.1	99.7	103.1	104.2	105.8	109.8	117.7	120.5	117.0	113.7	163.3
200	102.5	100.2	99.5	98.5	99.6	100.6	102.2	104.4	105.8	109.1	116.0	119.5	116.7	112.0	162.3
250	100.2	99.5	99.4	99.6	100.0	100.5	102.2	104.3	105.6	108.6	113.8	117.2	115.4	109.1	160.5
315	99.2	99.5	99.6	99.4	99.6	100.5	102.4	104.3	106.0	108.5	111.8	114.1	112.4	107.6	158.6
400	98.0	98.2	98.5	98.4	99.2	99.7	101.1	103.3	105.0	107.8	109.9	111.5	108.6	103.2	156.6
500	96.0	96.6	96.6	96.5	96.9	97.7	99.2	101.3	102.8	106.2	108.5	109.0	104.6	98.5	154.4
630	94.5	95.4	94.6	94.4	95.0	96.0	97.5	99.0	100.2	104.5	106.7	105.4	101.6	96.2	152.1
800	94.3	93.8	92.9	92.8	93.1	93.5	95.4	96.4	98.0	102.9	104.5	102.0	98.2	94.8	149.9
1000	94.4	93.2	92.6	92.7	92.9	93.0	94.8	97.4	98.5	100.7	102.8	99.1	95.5	93.7	148.6
1250	95.4	95.7	95.9	94.3	94.9	95.3	96.5	99.1	100.3	100.0	99.5	96.9	94.4	92.2	148.8
1600	97.0	96.8	97.2	96.5	96.9	96.7	98.6	100.8	100.8	100.2	98.8	96.8	93.7	91.6	149.7
2000	99.1	98.8	99.0	97.3	96.5	97.6	98.2	100.7	100.3	100.5	99.5	96.9	93.3	90.8	150.0
2500	99.8	98.4	97.1	96.7	96.4	98.3	99.5	100.4	100.6	100.2	99.3	96.5	94.0	90.8	150.1
3150	101.2	100.4	103.5	101.8	102.0	103.9	109.4	109.2	108.2	106.0	103.1	101.0	99.0	98.0	157.0
4000	99.6	99.7	101.2	100.5	99.9	101.4	106.3	104.7	105.4	106.2	103.0	100.1	97.4	95.8	154.6
5000	96.5	96.0	96.2	95.5	95.6	98.6	100.6	101.6	100.7	100.0	98.3	96.7	93.5	90.2	150.0
6300	96.7	96.7	98.8	97.2	97.6	101.2	104.4	104.5	103.6	102.3	99.7	96.7	94.2	92.7	152.6
8000	94.8	95.2	95.6	94.5	95.5	98.4	100.8	101.6	102.3	100.8	99.6	95.2	92.7	90.2	150.4
10000	92.8	92.8	93.3	93.2	93.4	98.7	100.8	101.2	101.0	99.8	96.6	94.0	91.2	87.4	149.5

AVERAGE NET REFERRED THRUST, FN/DELTA = 18321.1 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED, N1/VTHETA = 6296.0 RPM
AVERAGE JET EXHAUST VELOCITY = 1512.9 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.76

TOTAL PWL= 171.5

TABLE A-2. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH MODIFIED NACELLE

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 154, 155, AND 156 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	68.4	71.8	70.4	72.2	72.1	71.5	71.8	72.0	72.7	73.7	74.2	75.3	75.4	75.8	124.4
A	63	69.9	68.3	69.1	69.6	70.1	71.2	71.2	71.9	72.6	72.9	73.4	73.7	74.1	73.8	123.3
N	80	71.7	69.5	69.9	71.7	72.3	73.2	72.6	72.2	72.0	72.2	73.2	73.9	73.7	72.8	123.9
D	100	71.1	72.3	73.6	73.7	74.0	74.1	73.0	72.6	73.6	73.7	74.0	75.2	75.2	74.0	125.2
	125	71.4	72.6	72.2	72.7	72.6	73.1	74.1	74.1	74.6	74.9	76.0	77.0	77.3	73.9	125.7
C	160	71.7	72.5	73.4	72.6	72.4	72.3	74.2	75.1	74.8	74.7	75.3	76.0	76.6	73.6	125.6
E	200	71.2	73.1	74.1	73.5	74.1	74.0	72.9	73.0	74.1	73.9	74.2	74.5	74.0	72.2	125.1
N	250	73.1	74.1	73.3	73.3	72.5	73.7	73.8	74.8	75.1	76.0	74.9	74.7	73.6	72.6	125.6
T	315	73.9	73.5	72.7	72.9	72.1	73.2	73.0	74.5	74.9	74.9	73.9	74.3	72.5	71.7	125.1
E	400	80.8	75.5	78.9	81.3	75.1	73.5	72.7	79.4	77.1	79.7	77.0	79.2	78.0	74.7	129.2
R	500	72.5	72.2	72.6	71.0	70.0	71.1	70.8	72.9	73.0	74.5	74.3	71.8	69.0	68.3	123.5
	630	82.1	80.8	79.2	77.1	74.6	72.6	73.5	73.0	72.1	75.3	76.0	74.3	71.8	70.6	127.4
F	800	77.9	74.5	71.7	70.5	68.8	71.1	69.9	69.2	69.2	73.3	73.2	72.3	68.2	66.7	123.2
R	1000	78.5	71.7	72.1	69.8	70.0	70.9	69.1	70.6	70.1	73.5	73.9	70.7	68.7	68.3	123.2
E	1250	75.4	71.0	72.0	69.7	71.2	70.4	68.6	70.8	71.3	73.5	72.9	70.7	67.6	67.3	122.7
Q	1600	72.4	70.8	71.0	69.9	68.7	67.7	68.3	70.2	71.5	70.2	68.6	67.1	65.3	64.5	120.9
U	2000	78.5	81.4	77.5	73.9	73.8	68.9	69.8	71.2	72.2	72.1	70.8	69.6	67.3	65.9	125.4
E	2500	81.2	86.2	82.8	77.0	78.1	70.8	72.9	74.1	73.9	73.7	73.3	70.2	68.2	65.9	129.2
N	3150	76.9	77.5	73.7	71.1	69.0	68.1	72.0	75.7	74.8	73.8	72.5	69.4	65.7	63.9	124.5
C	4000	79.1	78.1	77.1	74.5	74.0	74.9	77.7	79.8	79.4	80.3	77.5	74.5	71.3	70.0	128.8
Y	5000	78.7	78.6	77.6	72.6	70.5	69.3	71.6	74.8	75.5	75.9	74.8	71.5	67.5	65.0	125.7
,	6300	77.5	77.1	74.7	72.9	70.4	69.5	72.1	75.7	76.0	76.7	76.4	72.9	68.1	65.4	125.7
H	8000	77.2	75.6	73.2	72.7	70.4	69.5	72.5	75.5	76.2	76.5	74.8	70.0	68.0	65.5	125.2
Z	10000	74.1	73.5	69.9	68.7	68.7	68.9	72.2	77.0	76.1	75.5	73.6	69.6	65.5	64.5	124.3

AVERAGE NET REFERRED THRUST, FN/DELTA = 1362.7 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 2204.9 RPM
AVERAGE JET EXHAUST VELOCITY = 344.7 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.04

TOTAL PWL= 139.4

TABLE A-2. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH MODIFIED NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 154, 155, AND 156 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	74.8	77.5	77.5	78.0	78.5	79.2	80.7	81.6	82.4	82.8	84.0	84.7	86.2	85.8	133.3
A	63	79.1	78.0	78.3	78.5	80.1	80.7	81.3	82.5	83.2	84.3	85.5	86.6	86.8	86.6	134.5
N	80	81.5	78.5	79.3	80.8	82.5	84.2	83.9	83.7	84.2	84.6	86.2	87.8	87.8	86.7	135.8
D	100	79.8	80.5	81.6	82.5	83.1	83.5	83.0	83.6	84.1	85.0	86.7	88.2	88.2	85.9	135.9
	125	80.3	81.8	82.5	83.4	83.3	83.2	83.9	84.3	84.6	85.1	86.5	87.9	87.9	83.9	136.0
C	160	81.3	82.0	83.2	82.7	82.0	83.1	83.8	84.7	84.8	84.8	85.5	86.7	87.0	81.8	135.6
E	200	79.9	81.5	81.5	80.5	81.5	81.9	81.8	82.9	83.5	82.8	83.2	84.0	84.5	80.9	133.8
N	250	80.7	81.6	80.9	80.5	80.9	82.8	82.7	84.0	84.5	84.6	83.9	82.3	83.4	81.1	134.3
T	315	81.1	80.9	81.1	81.9	82.2	83.4	83.0	83.8	84.0	83.8	83.6	82.4	82.1	81.1	134.3
E	400	80.1	81.0	81.7	81.4	81.6	82.9	83.0	84.5	84.7	85.1	83.2	82.7	80.1	79.5	134.4
R	500	80.6	81.5	82.1	80.1	78.8	80.0	80.0	81.7	81.8	82.8	82.7	81.3	78.6	77.9	132.4
	630	83.5	85.8	85.2	81.1	78.6	78.5	78.6	80.0	79.3	81.3	82.1	79.0	79.0	77.2	132.5
F	800	78.3	77.6	77.2	76.7	76.2	75.9	76.8	77.5	77.3	78.4	79.0	76.5	76.1	74.4	128.6
R	1000	83.7	84.2	81.8	79.8	77.9	77.4	76.8	77.6	78.8	79.9	79.1	76.1	74.9	74.5	130.8
E	1250	81.0	79.1	78.1	76.7	76.5	76.2	77.9	77.9	80.7	80.5	78.8	75.4	74.1	73.5	129.6
Q	1600	80.7	78.8	79.3	78.9	77.6	77.7	78.1	79.1	80.4	80.5	78.4	77.3	75.2	74.1	130.2
U	2000	84.8	84.1	82.7	80.5	79.3	78.8	79.2	79.3	79.6	80.2	83.1	77.6	75.6	74.2	132.0
E	2500	87.5	87.6	84.0	81.1	78.7	77.3	77.4	78.4	78.1	78.1	76.9	74.3	72.6	71.1	132.2
N	3150	87.7	85.1	82.5	79.8	77.8	77.0	77.2	78.5	77.6	78.2	76.9	74.3	72.2	70.2	131.3
C	4000	92.3	91.0	92.4	90.2	86.4	83.8	82.2	82.7	81.8	82.2	82.3	78.8	76.4	73.9	138.0
Y	5000	88.5	89.8	86.4	84.8	83.0	82.4	82.5	84.7	84.5	86.1	84.0	79.0	75.8	74.9	136.1
,	6300	90.3	91.7	88.5	87.8	87.3	86.2	88.4	91.1	89.1	90.4	87.9	82.9	80.2	78.4	139.9
H	8000	89.0	89.4	86.1	84.6	83.2	80.9	82.3	85.6	84.7	87.1	85.3	80.5	78.3	76.1	136.3
Z	10000	87.5	87.6	84.1	82.1	81.5	80.8	82.8	85.8	85.0	86.7	83.2	79.1	75.2	74.9	135.4

AVERAGE NET REFERRED THRUST, FN/DELTA = 3815.3 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 3545.3 RPM
AVERAGE JET EXHAUST VELOCITY = 582.3 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.11

TOTAL PWL= 148.5

TABLE A-2. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH MODIFIED NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 154, 155, AND 156 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	89.3	81.1	80.9	81.4	82.3	83.1	84.1	85.0	86.2	87.6	90.1	92.4	94.0	93.4	139.3
A	63	81.6	81.1	81.1	81.7	82.8	84.1	86.2	87.4	88.2	89.5	91.9	94.6	96.0	95.0	140.9
N	80	85.6	82.8	83.3	84.6	86.3	88.1	88.3	89.0	89.6	90.9	93.2	95.8	96.6	94.6	142.2
D	100	84.7	86.2	87.1	87.9	89.2	89.2	88.1	88.4	89.8	91.4	94.0	96.7	96.4	93.1	142.6
	125	85.1	86.0	86.4	87.6	88.0	87.5	88.4	89.3	90.3	91.6	94.1	96.1	95.3	90.4	142.1
C	160	86.2	86.9	88.1	87.7	87.3	87.5	88.5	89.5	90.1	91.0	92.9	95.1	93.7	88.8	141.5
E	200	85.7	86.7	86.4	85.5	86.6	87.1	87.4	88.5	89.1	89.3	90.3	92.4	91.2	87.4	139.9
N	250	86.3	85.7	85.5	85.2	85.8	87.0	87.5	89.0	89.7	90.0	89.9	90.6	89.6	86.8	139.6
T	315	85.2	85.0	85.3	85.9	86.5	87.4	87.7	88.8	89.3	89.3	89.6	89.3	87.4	86.4	139.3
E	400	83.8	84.7	85.6	85.7	86.1	87.3	87.8	89.4	89.4	89.6	88.0	88.5	85.3	84.6	139.1
R	500	81.7	83.4	83.8	83.6	84.0	86.2	85.9	87.0	86.5	87.3	87.1	86.2	83.7	82.6	137.1
	630	81.2	81.9	81.8	81.1	81.5	82.6	83.2	83.4	83.1	84.5	84.9	83.4	82.5	80.8	134.4
F	800	81.0	80.5	80.0	78.9	79.0	79.1	80.5	81.0	80.9	82.4	82.9	81.0	79.8	78.1	132.0
R	1000	82.6	80.5	79.9	79.1	78.9	79.4	80.2	81.2	82.2	83.3	82.7	80.2	78.5	77.5	132.2
E	1250	83.6	82.4	81.9	81.3	81.2	80.8	81.9	82.7	84.2	84.4	81.7	80.4	78.5	76.6	133.5
Q	1600	82.9	80.8	79.9	80.6	80.7	81.9	82.4	84.1	84.7	84.5	82.5	80.9	78.3	76.7	133.8
U	2000	85.3	84.7	82.9	81.8	82.2	82.1	82.6	83.6	82.7	83.9	82.2	80.6	78.8	76.2	134.1
E	2500	89.5	91.0	88.4	87.3	90.8	88.7	83.4	83.9	84.5	86.7	83.4	82.1	79.6	77.7	138.6
N	3150	89.3	87.4	85.1	84.6	83.4	82.2	81.8	82.0	81.3	81.4	80.3	78.6	76.2	73.6	134.6
C	4000	90.6	90.4	87.7	85.2	83.8	83.7	82.4	84.9	82.9	85.0	82.2	79.7	76.6	75.2	136.5
Y	5000	94.4	96.3	91.4	89.7	88.4	87.6	86.7	89.8	88.7	91.8	88.6	84.2	80.6	78.7	141.5
,	6300	91.6	92.4	91.4	89.6	88.1	88.6	89.0	90.9	89.4	91.2	87.5	83.5	81.5	79.4	140.9
H	8000	92.9	92.8	91.1	91.1	88.6	88.1	89.9	93.1	92.1	94.1	90.1	86.0	83.9	81.9	142.3
Z	10000	91.8	92.2	89.2	86.7	86.7	85.1	86.3	89.6	88.6	90.3	86.8	83.6	80.4	79.3	139.5

AVERAGE NET REFERRED THRUST, FN/DELTA = 6078.0 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 4297.9 RPM
AVERAGE JET EXHAUST VELOCITY = 778.6 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.20

TOTAL PWL= 153.2

TABLE A-2.– NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH MODIFIED NACELLE-Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 154, 155, AND 156 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	90.8	82.4	82.3	82.7	83.3	83.9	85.1	87.2	87.8	90.2	92.9	95.8	98.0	97.3	142.3
A	63	82.3	81.8	81.9	82.5	83.8	85.7	87.7	89.2	89.8	92.1	94.8	98.2	99.5	98.1	143.8
N	80	86.0	83.8	85.1	85.8	87.2	89.4	90.0	90.9	91.8	93.8	96.7	99.8	100.4	98.4	145.3
D	100	86.8	88.6	39.3	90.1	91.2	90.9	90.0	90.7	92.0	94.4	97.3	100.4	100.1	96.9	145.7
	125	86.8	87.6	88.0	89.4	89.9	89.6	90.2	91.5	92.5	94.2	97.4	99.6	98.7	95.0	145.0
C	160	88.3	88.9	89.9	89.5	88.9	89.7	90.6	91.9	92.5	93.3	96.1	98.7	96.8	92.7	144.3
E	200	87.8	88.7	88.1	87.4	88.6	89.2	89.4	90.7	91.6	92.1	93.9	96.1	94.5	91.3	142.7
N	250	88.4	87.6	87.5	87.1	87.6	88.9	89.6	91.3	92.1	92.5	93.1	93.8	92.5	89.9	142.1
T	315	87.1	87.1	87.4	37.7	87.9	89.0	89.4	90.7	91.5	91.9	92.3	92.6	90.1	89.7	141.6
E	400	85.7	86.7	97.2	87.3	37.6	88.8	89.6	91.2	91.4	91.9	90.9	91.1	88.1	87.6	141.1
R	500	83.7	85.4	95.7	85.9	86.0	88.1	88.0	89.1	88.7	89.8	89.6	88.7	86.7	85.8	139.3
	630	82.7	83.3	83.4	83.0	83.5	84.9	85.4	85.7	85.0	87.0	87.3	85.8	85.1	83.3	136.5
F	800	82.5	81.9	81.7	80.6	82.3	81.3	82.7	82.9	82.6	84.5	85.5	83.6	82.7	81.2	134.2
R	1000	84.0	81.5	80.9	80.4	80.6	81.0	81.8	83.3	84.1	86.0	84.3	83.0	81.1	80.3	134.2
E	1250	83.9	82.9	82.0	81.8	82.6	82.6	83.9	84.8	86.4	86.9	84.8	83.4	80.9	80.1	135.4
Q	1600	85.5	82.6	82.3	82.4	82.5	83.7	84.9	86.6	86.7	87.0	85.5	83.8	81.2	79.7	136.1
U	2000	86.7	84.8	83.2	82.2	82.1	83.5	84.3	85.2	85.0	86.1	84.5	82.8	80.2	78.4	135.5
E	2500	89.0	90.5	91.7	91.6	87.5	85.2	85.8	85.5	87.6	91.2	86.3	85.5	81.4	80.2	139.6
N	3150	88.8	87.1	84.7	84.0	83.1	83.1	83.2	83.8	83.4	83.9	82.8	81.2	78.6	77.0	135.3
C	4000	90.3	89.7	87.1	85.1	84.4	84.4	83.5	85.0	83.8	84.9	82.5	80.6	77.7	76.3	136.5
Y	5000	92.6	93.9	92.8	90.2	87.7	89.0	87.7	89.5	89.5	89.8	86.6	83.3	81.6	78.9	140.9
.	6300	92.0	92.3	90.6	89.7	87.8	88.6	88.7	91.1	89.7	90.6	87.5	83.5	82.0	79.9	140.8
H	8000	95.5	92.9	91.3	91.2	90.3	89.5	92.0	95.0	93.2	95.0	90.4	86.5	84.7	83.4	143.5
Z	10000	91.7	92.8	89.2	87.7	88.1	86.5	88.0	92.0	91.2	92.1	89.1	86.7	83.1	82.3	141.0

AVERAGE NET REFERRED THRUST, FN/DELTA = 7240.0 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED, N1/VTHETA = 4602.5 RPM
AVERAGE JET EXHAUST VELOCITY = 856.6 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.24

TOTAL PWL= 155.3

TABLE A-2. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH MODIFIED NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 154, 155, AND 156 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	92.2	83.8	83.4	83.6	84.5	85.2	86.8	87.9	89.6	92.2	95.4	98.5	100.6	99.8	144.6
A	63	83.5	83.0	83.1	83.8	85.0	87.1	89.8	91.0	91.5	94.4	97.6	101.1	103.0	101.0	146.6
N	80	86.9	85.4	86.9	87.1	88.9	90.5	91.9	92.9	94.0	96.1	99.9	103.1	104.0	100.9	148.1
D	100	88.6	89.8	91.1	91.3	92.7	92.0	92.2	93.3	94.7	97.0	100.3	104.1	103.6	99.6	148.6
	125	88.8	89.4	89.9	91.2	91.8	91.1	92.4	93.5	94.8	96.9	100.4	103.2	101.8	98.3	147.9
C	160	90.8	90.8	91.8	91.4	90.9	91.5	93.0	94.0	94.7	96.1	99.2	102.0	99.1	95.7	147.0
E	200	90.3	90.8	90.2	89.1	90.7	91.1	91.6	93.3	94.4	94.6	96.7	99.5	96.5	93.6	145.3
N	250	91.0	89.5	89.4	89.5	90.1	90.9	91.9	93.8	94.4	95.3	96.2	97.0	95.1	91.7	144.7
T	315	89.3	89.1	89.3	89.8	89.9	90.7	92.0	93.1	94.1	94.4	95.2	95.4	92.6	91.4	143.9
E	400	87.9	88.5	89.2	89.0	89.6	90.4	91.5	93.0	93.5	93.8	93.7	93.5	90.3	89.4	143.1
R	500	86.1	87.5	87.5	87.7	88.0	89.6	89.6	90.5	90.9	92.1	92.3	91.3	88.6	87.6	141.3
	630	85.1	85.4	85.5	84.9	85.6	86.9	87.4	87.4	87.5	88.9	90.1	88.2	87.1	85.6	138.7
F	800	85.1	84.6	84.3	82.9	83.2	83.5	84.1	84.4	85.1	86.7	87.8	86.0	84.8	82.8	136.3
R	1000	86.8	84.5	83.6	82.8	83.0	83.1	83.9	85.1	86.2	87.5	87.1	85.2	83.0	81.8	136.3
E	1250	85.6	84.7	83.5	83.0	84.1	84.2	85.8	87.0	87.7	88.0	86.5	85.0	82.6	81.0	137.0
Q	1600	86.5	83.8	83.3	83.6	84.4	85.4	85.9	88.0	87.3	87.5	86.0	84.9	82.3	80.4	137.1
U	2000	87.9	85.6	84.0	83.6	84.1	85.3	86.3	87.4	86.4	87.9	86.3	84.2	81.3	79.1	137.2
E	2500	92.4	93.6	95.6	91.9	88.1	87.2	87.3	86.5	87.7	88.4	87.6	85.6	82.9	79.7	141.0
N	3150	90.4	91.0	92.3	88.9	85.9	85.9	85.6	85.6	85.8	85.9	85.1	83.6	80.7	77.7	138.6
C	4000	91.1	89.9	87.5	85.6	85.3	85.4	84.8	86.4	85.0	86.3	84.1	82.3	78.9	76.8	137.5
Y	5000	94.1	93.2	90.0	89.8	88.6	88.1	87.4	89.5	88.0	90.6	87.9	84.2	81.5	79.4	140.6
.	6300	93.4	93.4	92.3	91.1	89.3	89.4	89.1	90.4	89.8	90.3	87.6	84.4	82.6	79.5	141.4
H	8000	95.1	94.3	91.8	91.6	90.7	90.4	92.5	93.9	94.1	96.3	91.1	86.7	84.8	82.0	144.0
Z	10000	92.4	92.5	90.3	88.4	88.4	87.5	88.9	92.5	93.1	93.1	90.2	87.4	83.8	81.5	141.8

AVERAGE NET REFERRED THRUST, FN/DELTA = 8583.6 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 4909.7 RPM
AVERAGE JET EXHAUST VELOCITY = 946.0 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.30

TOTAL PWL= 157.5

TABLE A-2. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH MODIFIED NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 154, 155, AND 156 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	91.1	85.1	84.9	85.9	86.3	87.2	89.2	91.0	91.9	95.3	99.4	102.9	104.9	104.3	148.5
A	63	85.2	85.3	85.7	86.2	87.7	89.5	92.2	93.3	94.6	98.2	102.3	105.6	107.4	105.1	150.7
N	80	88.4	87.0	89.4	89.4	91.8	92.9	94.6	95.9	96.5	100.0	105.1	107.9	108.5	105.6	152.5
D	100	90.8	92.1	92.5	93.0	94.4	94.0	95.4	96.8	98.3	101.2	105.9	109.7	108.8	105.4	153.5
	125	92.0	92.4	93.0	94.2	94.6	94.1	95.7	97.1	98.6	101.4	106.3	109.8	107.6	105.0	153.4
C	160	95.0	93.8	94.7	94.9	94.2	95.1	96.1	97.9	98.7	100.6	105.1	108.3	105.1	102.1	152.2
E	200	94.6	94.1	93.3	92.3	93.7	94.2	95.4	96.9	97.9	99.2	102.6	105.7	102.5	99.1	150.2
N	250	94.2	92.6	92.8	93.0	93.9	94.4	95.5	97.1	98.2	99.6	101.5	102.7	100.3	96.5	149.1
T	315	92.8	92.7	92.7	93.0	93.5	94.2	95.5	96.8	98.1	98.8	100.4	100.4	97.1	95.8	148.1
E	400	91.1	91.7	92.3	92.2	92.8	93.7	94.8	96.2	97.1	98.2	98.7	98.4	94.4	93.7	147.0
R	500	89.7	90.6	90.6	90.9	91.2	92.8	93.4	94.3	94.4	96.1	97.1	95.9	92.8	91.8	145.2
	630	88.3	88.9	89.4	88.4	89.5	91.1	91.6	91.5	91.5	93.3	94.9	92.3	91.6	89.8	142.9
F	800	88.4	88.0	87.6	86.5	87.6	87.7	89.1	88.6	89.6	91.1	92.3	89.7	88.4	86.7	140.5
R	1000	90.3	88.0	87.2	86.6	86.0	87.3	87.9	89.3	89.8	91.4	91.4	88.7	86.5	85.9	140.2
E	1250	88.1	87.1	86.4	86.7	87.3	87.9	89.3	90.8	92.0	92.2	90.2	88.2	86.0	84.5	140.7
Q	1600	89.0	87.1	85.9	86.7	88.1	88.6	89.8	91.6	91.6	91.5	89.3	87.6	85.5	84.4	140.7
U	2000	89.0	88.4	87.3	86.6	87.8	88.5	89.6	90.6	90.7	90.9	89.6	87.7	85.3	83.5	140.4
E	2500	90.5	90.3	90.6	88.6	88.1	89.3	89.9	90.6	90.3	91.0	90.3	88.1	85.2	82.9	141.1
N	3150	97.3	97.4	97.6	92.4	92.5	91.6	91.2	91.3	90.1	90.9	90.8	89.0	86.3	83.3	144.2
C	4000	92.7	91.4	90.4	90.6	89.8	89.1	89.1	88.6	88.8	89.3	87.9	85.5	83.2	80.8	140.7
Y	5000	95.7	93.2	91.2	90.9	90.1	89.9	90.3	94.1	93.2	93.0	89.2	86.5	84.3	82.3	142.9
,	6300	98.4	99.3	97.0	94.8	95.0	92.3	92.5	95.2	95.1	97.0	92.1	88.5	86.5	84.7	146.3
H	8000	95.0	94.9	92.7	93.3	92.7	92.3	92.9	95.2	95.8	98.4	92.4	88.6	86.6	84.3	145.4
Z	10000	94.8	95.7	93.0	91.5	92.0	90.5	92.5	96.4	95.9	95.6	92.3	89.1	85.6	84.2	144.8

AVERAGE NET REFERRED THRUST, FN/DELTA = 10922.0 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 5353.7 RPM
AVERAGE JET EXHAUST VELOCITY = 1105.6 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.41

TOTAL PWL= 161.9

TABLE A-2. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH MODIFIED NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 154, 155, AND 156 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	86.2	86.4	86.8	86.8	88.2	88.5	90.7	93.8	94.5	98.0	102.8	106.2	108.9	108.1	152.0
A	63	87.3	87.2	87.9	88.3	89.3	91.1	93.6	95.7	96.8	100.8	105.7	109.5	110.8	108.8	154.1
N	80	90.0	88.8	90.8	91.0	92.8	94.2	95.5	98.0	99.0	102.9	108.2	111.6	112.4	109.3	155.9
D	100	92.9	93.2	93.7	94.1	95.2	95.7	97.3	100.0	101.4	104.6	110.2	114.1	112.7	109.5	157.5
	125	94.5	94.4	95.3	95.7	96.4	95.8	97.9	100.8	101.7	105.5	111.1	114.7	112.0	110.1	157.9
C	160	98.3	96.5	97.6	97.6	96.9	97.2	98.9	101.5	102.3	104.6	110.6	114.0	110.8	108.8	157.3
E	200	98.2	97.0	95.9	95.2	96.1	96.8	98.4	101.2	101.5	103.3	108.1	110.6	109.0	105.3	154.9
N	250	97.1	95.5	95.9	95.9	96.4	96.9	98.2	101.1	101.9	102.9	106.1	108.4	106.3	102.5	153.5
T	315	95.2	95.3	95.7	95.9	96.0	96.8	98.3	100.9	101.8	102.7	104.4	105.3	102.3	100.9	152.0
E	400	94.1	94.6	94.9	95.1	95.6	96.3	97.6	100.1	100.6	102.0	102.9	102.6	98.8	97.9	150.6
R	500	92.4	93.3	93.4	93.5	94.0	95.3	96.2	98.3	98.4	100.3	101.4	99.8	96.6	95.4	148.8
	630	91.2	92.2	92.3	91.8	92.5	93.8	95.0	96.5	96.3	98.4	99.3	96.8	95.3	93.6	146.9
F	800	91.2	91.2	90.5	90.0	90.2	91.0	92.4	93.9	93.8	96.3	96.9	94.3	92.7	91.0	144.6
R	1000	92.6	90.8	89.9	89.2	89.2	89.7	90.6	93.3	92.9	95.0	95.3	92.1	90.2	89.7	143.4
E	1250	91.1	89.4	89.3	89.1	89.7	89.9	91.1	94.1	94.2	94.3	93.2	90.9	89.3	88.5	143.2
Q	1600	91.0	89.6	88.6	89.5	90.2	91.1	91.9	95.5	94.4	94.1	92.4	91.1	89.1	88.2	143.5
U	2000	91.0	90.2	89.3	89.8	90.3	91.6	91.8	94.7	93.8	93.9	92.8	91.1	88.8	87.1	143.4
E	2500	92.1	91.6	90.0	90.0	90.8	91.9	92.5	94.2	93.2	93.5	92.5	90.4	88.1	86.2	143.4
N	3150	100.2	99.4	95.7	95.6	95.6	94.9	93.9	95.7	94.4	94.9	93.6	91.2	88.7	87.8	146.8
C	4000	93.9	93.5	92.5	92.5	93.0	92.0	91.7	93.4	92.0	92.2	91.2	89.4	86.4	84.8	143.5
Y	5000	96.7	94.4	93.0	93.1	92.6	92.4	92.3	95.0	95.2	93.4	91.4	89.2	86.5	85.1	144.6
,	6300	96.4	96.0	95.5	95.0	94.7	94.3	94.7	99.3	101.0	97.6	94.3	91.4	89.3	87.3	147.8
H	8000	95.8	94.6	93.2	93.5	92.5	93.3	94.6	97.4	97.1	97.0	93.6	90.4	88.2	86.6	146.1
Z	10000	94.3	95.3	92.9	92.7	93.0	92.9	95.2	98.5	98.2	98.0	94.6	91.6	87.9	87.3	146.6

AVERAGE NET REFERRED THRUST, FN/DELTA = 13213.9 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 5706.4 RPM
AVERAGE JET EXHAUST VELOCITY = 1249.8 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.53

TOTAL PWL= 165.8

TABLE A-2. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH MODIFIED NACELLE - Continued

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 154, 155, AND 156 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

		ANGLES FROM ENGINE INLET CENTERLINE, DEGREES														
		15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
B	50	87.8	87.5	88.0	88.1	89.3	90.0	92.2	94.0	96.2	99.7	104.9	108.5	111.4	109.8	154.1
A	63	88.8	88.7	89.0	89.3	90.9	92.7	95.0	96.2	99.1	103.1	108.3	111.9	113.6	110.8	156.5
N	80	91.8	91.0	92.8	92.9	94.6	95.4	97.2	98.6	101.3	105.7	111.2	114.4	114.6	110.9	158.3
D	100	95.2	94.7	95.0	95.7	96.6	97.3	99.3	100.7	103.5	107.2	114.0	117.2	115.1	111.8	160.3
	125	96.8	96.6	97.3	97.1	98.0	98.3	100.6	101.7	104.1	108.7	115.3	118.1	114.3	112.4	161.1
C	160	100.8	99.0	99.7	99.7	99.4	99.2	101.7	102.5	104.9	108.0	115.0	118.0	114.1	112.1	161.0
E	200	101.2	99.5	98.2	97.8	98.5	99.6	101.2	102.0	104.5	106.9	112.7	116.2	113.5	109.4	159.4
N	250	99.5	98.2	98.5	98.7	98.9	99.4	100.9	102.1	104.6	106.1	110.5	113.0	111.0	106.1	157.2
T	315	97.9	97.8	98.6	98.6	98.6	99.5	101.1	101.8	104.7	106.0	108.5	109.5	106.7	105.0	155.4
E	400	96.7	96.8	97.4	97.5	97.8	98.5	100.0	100.9	103.2	104.8	106.7	106.7	102.9	101.3	153.5
R	500	94.6	95.5	95.6	95.5	95.8	97.3	98.3	99.1	100.8	103.0	104.8	103.0	99.6	98.2	151.3
	630	93.2	94.2	94.1	93.4	94.2	95.7	96.9	97.1	98.4	101.0	102.2	99.9	97.6	96.6	149.2
F	800	93.1	93.3	92.4	92.1	92.5	93.0	94.5	94.7	96.4	99.0	99.5	97.0	95.1	93.7	146.9
R	1000	94.2	92.7	91.7	91.6	91.5	92.3	93.6	94.6	96.3	97.5	98.1	94.7	92.9	92.1	145.9
E	1250	93.0	91.8	91.4	91.7	92.3	93.1	94.8	95.6	97.3	97.0	96.3	93.8	92.1	91.6	145.9
Q	1600	92.8	91.5	91.3	92.1	93.1	94.2	95.4	96.7	97.7	96.0	94.7	93.6	92.1	90.9	146.1
U	2000	94.4	93.1	93.5	92.1	93.5	94.4	95.6	96.1	97.3	96.7	95.9	93.6	91.2	89.8	146.3
E	2500	92.6	92.7	91.4	91.9	92.8	93.8	95.3	95.4	95.1	95.8	94.7	92.2	89.9	88.5	145.3
N	3150	98.8	97.4	96.4	97.8	95.1	95.2	96.6	98.0	96.7	96.9	93.9	92.3	89.9	88.2	147.6
C	4000	95.2	93.3	93.0	93.2	93.0	93.6	93.9	94.4	94.2	93.4	92.4	90.9	88.0	86.4	144.7
Y	5000	95.6	95.0	92.9	92.7	93.4	93.6	93.6	95.1	94.6	94.0	92.6	90.6	87.7	85.6	145.0
.	6300	94.1	94.9	93.9	94.4	93.8	94.9	96.8	99.5	100.2	97.8	94.2	91.5	89.2	87.0	147.6
H	8000	94.5	93.8	92.5	93.3	93.6	93.9	95.5	97.9	97.3	96.3	93.1	90.5	88.7	86.6	146.2
Z	10000	93.0	94.1	91.6	92.0	93.5	93.4	96.1	99.0	97.6	96.7	93.7	91.0	87.9	87.1	146.4

AVERAGE NET REFERRED THRUST, FN/DELTA = 15099.4 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 6001.2 RPM
AVERAGE JET EXHAUST VELOCITY = 1368.0 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.64

TOTAL PWL= 168.9

TABLE A-2. – NASA CONTRACT NAS1-7130. ANALYSIS OF STATIC NOISE TESTS AT EDWARDS AFB. TEST-STAND P&WA JT3D ENGINE WITH MODIFIED NACELLE - Concluded

SOUND PRESSURE LEVELS (SPLs) RECORDED DURING RUNS 154, 155, AND 156 AND AT A DISTANCE OF 150 FT FROM THE ENGINE

AVERAGE ONE-THIRD OCTAVE-BAND SPL, dB (RE .0002 MICROBARS)

BAND CENTER FREQUENCY, HZ	ANGLES FROM ENGINE INLET CENTERLINE, DEGREES 15	30	40	50	60	75	90	100	110	120	130	140	150	157	PWL
50	91.1	89.4	89.9	89.8	90.5	91.8	94.0	95.2	98.2	102.4	107.1	111.4	113.9	112.6	156.7
63	90.9	90.4	91.2	91.5	92.9	94.5	96.9	98.1	100.8	105.5	110.6	114.5	115.9	113.2	158.9
80	93.7	92.7	95.0	94.2	96.1	96.8	98.9	100.4	103.2	107.8	114.2	117.5	117.4	113.7	161.1
100	96.7	96.2	96.3	97.1	98.3	99.1	101.7	102.8	105.4	109.9	116.6	120.0	117.7	114.8	163.0
125	99.1	99.0	99.3	98.8	99.8	100.4	102.9	104.0	106.7	112.4	118.8	121.5	117.2	115.7	164.4
160	103.7	101.8	102.1	102.2	101.9	101.8	104.3	105.4	107.5	111.2	119.3	121.7	117.2	115.6	164.7
200	105.0	102.4	101.1	100.2	101.1	102.5	103.8	105.3	107.4	110.6	117.5	120.2	117.4	113.4	163.4
250	102.0	100.9	101.6	101.5	101.6	102.1	103.7	105.2	107.4	109.5	115.3	117.4	115.7	111.2	161.4
315	100.7	100.9	101.5	101.4	101.2	102.2	103.9	104.9	107.3	109.3	112.9	113.9	111.6	110.0	159.3
400	99.8	99.7	100.1	100.3	100.7	101.0	102.5	103.8	106.2	108.4	110.5	110.9	107.3	105.4	157.0
500	97.6	98.3	98.3	98.3	98.5	99.8	100.8	102.0	103.9	106.4	108.2	107.8	103.6	101.4	154.6
630	96.2	97.0	97.0	96.3	97.0	98.2	99.6	100.1	101.4	104.6	106.2	104.1	101.4	99.2	152.5
800	95.6	95.5	95.0	95.5	94.9	95.5	96.8	97.3	99.0	102.2	103.7	100.9	98.4	96.8	150.0
1000	96.1	94.7	94.2	94.0	94.0	94.5	95.4	97.0	98.8	100.7	101.5	98.3	96.4	95.3	148.7
1250	95.1	93.8	93.7	93.6	94.4	94.7	96.1	98.3	99.8	99.8	99.4	97.0	95.3	94.7	148.4
1600	94.5	93.5	92.9	94.1	94.9	96.1	97.4	99.6	100.3	99.7	98.3	97.6	95.3	94.6	148.7
2000	95.1	94.4	93.7	94.1	95.2	96.8	97.6	98.6	99.5	99.6	98.6	97.2	95.1	93.2	148.6
2500	95.6	94.3	93.7	94.2	95.0	96.2	97.3	97.3	98.4	98.8	98.0	96.1	93.7	91.8	148.0
3150	95.9	96.9	94.4	95.4	95.3	95.7	97.4	98.5	98.4	97.8	96.7	94.8	92.4	90.7	148.0
4000	96.4	97.1	94.3	95.2	95.4	95.8	96.1	96.7	97.1	96.8	96.0	94.3	91.5	90.1	147.3
5000	95.0	94.8	93.6	94.1	94.4	95.1	94.9	96.2	96.9	96.4	95.3	93.1	90.6	88.9	146.4
6300	95.2	95.3	94.0	95.4	95.3	95.8	97.2	99.7	98.4	98.3	95.9	93.5	91.4	89.6	148.0
8000	95.5	94.6	93.2	94.2	94.6	95.0	96.4	97.9	97.8	98.8	95.6	92.9	90.8	89.0	147.2
10000	93.4	94.1	92.2	92.9	94.3	93.1	94.9	99.2	99.0	97.5	95.8	92.5	89.8	89.0	147.0

AVERAGE NET REFERRED THRUST, FN/DELTA = 16933.9 LB
AVERAGE REFERRED LOW PRESSURE ROTOR SPEED,N1/VTHETA = 6286.0 RPM
AVERAGE JET EXHAUST VELOCITY = 1487.7 FT/SEC
AVERAGE ENGINE PRESSURE RATIO = 1.76

TOTAL PWL= 172.1

APPENDIX B

SAMPLE FLYOVER NOISE LEVELS FOR TEST-DAY ATMOSPHERIC CONDITIONS

This appendix contains sample output pages with the flyover noise levels calculated for the test-day atmospheric conditions. The following items are tabulated as a function of time during the flyover. (Each event number corresponds to a 0.25-sec interval.)

1 – One-third octave-band SPLs, corrected for frequency response and microphone pressure response, for the bands between 50 and 10 000 Hz.

2 – Instantaneous perceived-noise level, PNL(k), tone correction factor, C(k), and tone-corrected instantaneous perceived-noise level, PNLT(k). The index k denotes a function of time.

Three highlights of the calculations are included at the end of the tabulated values. These highlights show the instantaneous SPLs and noisiness values at the instant of the maximum instantaneous perceived noise level, PNLM, and at the instant of maximum instantaneous tone-corrected perceived noise level, PNLTM. The maximum SPLs and noisiness values in each band that occurred during the flyover and the corresponding composite perceived noise level, PNLP, are also shown.

The duration time used in the integration method of determining the duration correction factor, D, and the value of D are also listed on the highlight page. The effective perceived noise level, EPNL, calculated for the particular flyover is the sum of PNLTM and D and is listed at the bottom of the highlight page.

The last page of this Appendix contains a plot of PNLT(k) as a function of time during the flyover. The plot was generated under program control and was made on the same line-printer used for listing the tabulated values. These plots provided a rapid means for a qualitative and quantitative check of the calculations.

NASA CONTRACT NAS1-7130. ANALYSIS OF FLYOVER NOISE TESTS AT FRESNO
SEABOARD WORLD AIRLINES DC-8-55 FUSELAGE NO. 242
FOUR UNTREATED PWA JT3D-3B TURBOFAN ENGINES

FLYOVER - LANDING		TEST DATE - 9 FEB 1969	WET BULB - 51.8 DEG.F
REF.FN - 4275	LBS/ENG	FLIGHT NO.- 5	DRY BULB - 64.3 DEG.F
O.H. DIST.- 500	FEET	ITEM NO. - 12	REL.HUM. - 42.0 PERCENT
REF.N1 - 4334	RPM	STA. NO. - 10	ABS.HUM. - 6.27 GM/M3
EPR - 1.18		LOCATION - L	BAR.PRES. - 29.74 IN.HG
GROSS WT. - 186 000	LBS	REEL NO. - 10-1	WIND SPEED- 2 KNOTS
AIRSPEED - 137	KNOTS	PROG.NO. - E2QC	WIND DIR. - SE

EVENT NO. 76 = COUNTER NO. 6363.50

ONE-THIRD OCTAVE BAND TEST DAY SOUND-PRESSURE LEVEL, DB (RE 0.0002 MICROBARS)

	CENTER FREQUENCY, HZ													CENTER FREQUENCY, KHZ													
EVENT NO	50	63	80	100	125	160	200	250	315	400	500	630	800	1.	1.25	1.6	2.	2.5	3.15	4.	5.	6.3	8.	10	PNL(K) PNDB	C(K) DB	PNLT(K) PNDB
1	68	64	64	63	60	60	58	56	56	55	54	54	54	53	52	51	57	56	55	54	55	54	48	49	80.9	1.1	82.0
2	69	65	65	63	61	60	58	57	56	55	54	54	54	53	52	51	57	56	56	55	55	55	49	50	81.2	1.1	82.2
3	70	65	65	63	60	59	58	57	56	55	55	54	54	53	52	51	57	56	56	55	55	55	49	50	81.2	1.1	82.3
4	68	66	65	62	59	59	58	57	56	55	55	54	54	53	52	51	57	56	56	55	55	55	49	50	81.1	1.1	82.1
5	67	65	63	61	59	58	58	57	55	55	55	54	54	53	52	51	57	56	55	55	55	55	49	50	80.9	1.1	82.0
6	67	65	62	61	59	58	57	57	55	55	54	54	54	53	52	52	57	56	55	55	55	55	49	50	80.9	1.1	81.9
7	66	65	63	61	59	59	57	56	55	55	54	54	54	54	52	53	57	56	55	55	55	55	50	50	80.9	0.0	80.9
8	66	64	64	62	59	59	57	57	55	55	54	54	54	54	52	54	57	56	55	55	55	55	50	50	81.0	0.0	81.0
9	66	62	63	61	59	60	57	57	55	55	54	54	54	55	52	55	57	56	55	55	55	55	50	50	81.0	0.0	81.0
10	66	64	63	63	60	60	58	57	55	55	54	54	54	55	53	54	57	56	55	55	55	55	50	50	81.2	0.0	81.2
11	67	67	64	63	62	60	58	57	55	55	54	55	55	55	53	55	57	56	55	55	55	55	50	50	81.4	0.0	81.4
12	67	67	63	63	62	60	59	57	56	55	55	55	55	55	53	55	57	56	55	55	55	55	50	50	81.4	0.0	81.4
13	67	66	64	63	62	61	59	57	57	55	55	55	55	55	53	55	57	56	55	55	55	55	50	50	81.5	0.0	81.5
14	66	65	65	63	62	61	59	58	57	55	55	55	55	55	53	55	57	56	55	55	55	55	50	50	81.5	0.0	81.5
15	66	65	65	64	63	61	60	58	57	55	55	55	55	55	53	56	58	56	55	55	55	55	50	50	81.6	0.0	81.6
16	66	65	65	63	63	62	61	58	56	55	55	55	55	55	53	56	58	56	55	55	55	55	50	50	81.6	0.0	81.6
17	66	64	64	65	62	63	61	58	56	55	55	55	55	55	53	55	58	56	55	55	55	55	50	50	81.6	0.0	81.6
18	66	63	64	66	62	62	61	58	56	55	55	55	55	55	53	55	58	56	55	55	55	55	50	50	81.6	0.0	81.6
19	64	65	64	64	64	62	61	59	56	55	56	56	58	59	54	59	59	56	55	55	55	55	50	50	82.2	1.0	83.2
20	64	65	65	66	64	64	61	59	56	56	57	56	59	59	55	62	59	56	55	55	55	55	50	50	82.8	1.4	84.2
21	65	66	65	66	66	65	61	59	56	57	57	57	59	60	56	62	60	56	55	55	55	55	50	50	83.1	1.3	84.4
22	66	65	66	66	66	65	62	60	56	58	57	57	60	59	56	61	60	56	55	55	55	55	50	50	83.0	0.0	83.0
23	65	66	67	66	65	65	63	60	56	58	58	57	59	58	56	59	59	56	55	55	55	55	50	50	82.7	0.0	82.7
24	66	67	68	66	66	65	63	61	56	58	58	58	59	57	55	58	58	56	55	55	55	55	50	50	82.6	0.0	82.6
25	67	67	69	66	66	66	63	61	56	59	59	59	59	57	55	58	58	56	55	55	55	55	50	50	82.8	0.0	82.8
26	69	69	69	66	66	66	63	60	56	58	59	59	59	57	55	57	58	56	55	55	55	55	50	50	82.9	0.0	82.9
27	70	68	69	66	66	65	62	60	56	58	59	59	59	57	56	57	58	56	55	55	55	55	50	50	82.8	0.0	82.8
28	70	66	68	66	67	65	60	59	56	58	59	61	59	57	58	59	60	56	55	55	55	55	50	50	83.2	0.0	83.2
29	68	65	66	66	67	65	61	58	56	58	59	62	60	59	60	61	61	57	55	55	55	55	50	50	83.9	0.0	83.9

CONTINUED

ONE-THIRD OCTAVE BAND TEST DAY SOUND-PRESSURE LEVEL, DB (RE 0.0002 MICROBARS)

	CENTER FREQUENCY, HZ													CENTER FREQUENCY, KHZ													
EVENT NO	50	63	80	100	125	160	200	250	315	400	500	630	800	1.	1.25	1.6	2.	2.5	3.15	4.	5.	6.3	8.	10	PNL(K) PNDB	C(K) DB	PNLT(K) PNDB
30	68	64	65	65	65	64	61	58	56	58	59	62	61	60	61	61	62	57	55	55	55	55	50	50	84.1	0.0	84.1
31	69	66	66	66	65	63	60	58	56	59	59	63	60	59	61	61	62	57	55	55	55	55	50	50	84.1	0.0	84.1
32	71	67	67	67	65	64	61	58	56	60	59	63	59	59	61	61	62	57	55	55	55	55	50	50	84.3	1.1	85.4
33	73	68	66	68	67	64	62	58	56	60	60	63	59	58	60	61	61	57	55	55	55	55	50	50	84.2	1.1	85.3
34	73	68	68	68	67	64	62	58	56	60	61	62	58	58	58	59	60	57	55	55	55	55	50	50	83.8	0.0	83.8
35	73	69	67	68	67	64	61	58	57	60	62	62	57	57	57	59	60	57	55	55	55	55	50	50	83.5	0.0	83.5
36	72	67	68	68	67	64	60	57	58	60	62	62	57	58	57	59	60	57	55	55	55	55	50	50	83.6	0.0	83.6
37	71	68	68	68	67	64	60	58	58	60	62	62	57	60	58	60	60	57	55	55	55	55	50	50	83.8	0.0	83.8
38	71	68	67	68	66	64	60	57	57	60	62	62	57	61	59	62	61	57	56	55	55	55	50	50	84.1	1.1	85.2
39	70	69	68	68	67	64	60	57	57	60	62	62	57	61	59	63	61	58	56	55	55	55	50	50	84.5	1.1	85.7
40	72	70	69	69	67	65	60	57	57	60	62	61	57	61	59	63	61	58	56	55	55	55	50	50	84.6	1.1	85.7
41	72	70	69	69	68	64	60	57	57	60	62	61	57	61	59	64	62	58	56	55	55	55	50	50	85.0	1.3	86.3
42	72	70	69	69	68	64	59	57	57	60	62	61	57	61	59	66	63	59	57	55	55	55	50	50	85.8	1.8	87.5
43	73	69	69	69	67	63	59	57	57	62	62	61	57	62	59	67	63	59	57	55	55	55	50	50	86.1	2.0	88.1
44	73	71	68	69	67	64	59	57	58	63	63	61	58	64	60	67	64	59	58	55	55	55	50	50	86.6	1.9	88.4
45	73	70	69	69	66	64	59	57	59	65	65	61	59	67	62	69	67	61	58	55	55	55	50	50	87.7	2.1	89.8
46	73	71	70	70	64	63	59	57	61	67	67	62	60	67	62	69	68	63	59	55	55	55	50	50	88.5	1.9	90.4
47	72	70	70	70	64	64	60	58	62	67	67	62	62	68	63	70	68	64	60	55	55	55	50	50	88.8	1.7	90.6
48	72	68	69	70	65	64	60	58	64	68	67	62	63	68	64	69	68	64	60	55	55	55	50	50	88.8	1.2	90.1
49	72	69	69	70	67	65	59	58	64	69	67	61	63	68	64	68	67	63	61	55	55	55	50	50	88.6	1.2	89.8
50	73	69	69	70	67	65	59	58	64	68	67	61	63	67	64	68	66	63	61	55	55	55	50	50	88.3	1.1	89.5
51	75	72	72	72	67	64	58	61	66	68	66	61	63	67	64	67	66	63	62	55	55	55	50	50	88.2	0.0	88.2
52	77	73	72	72	66	63	59	62	66	68	66	61	63	66	64	68	66	63	62	55	55	55	50	50	88.6	0.0	88.6
53	75	73	72	72	67	64	60	63	67	68	66	62	65	67	67	70	69	65	64	56	55	55	50	50	90.1	0.0	90.1
54	74	73	73	73	68	64	60	64	67	69	67	62	67	68	67	72	69	66	66	57	55	55	50	50	91.0	1.2	92.1
55	74	74	73	71	67	63	61	66	69	69	67	64	68	68	68	73	71	69	68	60	55	55	50	50	92.2	1.2	93.5
56	74	74	73	72	67	63	62	68	69	69	68	64	70	68	69	75	72	69	70	60	55	55	50	50	93.6	1.7	95.3
57	75	74	73	73	67	63	63	69	70	70	68	65	71	68	70	76	73	70	72	63	55	55	50	50	94.7	2.0	96.7
58	75	75	73	72	69	63	65	70	72	71	69	67	71	68	70	76	74	71	75	64	56	55	50	50	96.5	2.7	99.2
59	76	74	73	72	69	63	66	70	72	70	68	68	71	70	70	76	74	72	78	66	57	55	50	50	98.3	3.0	101.3
60	75	73	73	72	68	62	67	71	71	71	68	69	70	72	72	78	75	72	81	67	57	56	50	50	99.9	3.7	103.5
61	75	74	75	73	67	62	69	73	72	71	68	70	70	73	72	78	75	73	81	67	58	57	50	50	100.1	3.5	103.6
62	76	74	75	72	66	63	70	73	73	71	68	72	70	74	74	80	76	76	83	69	60	60	50	50	102.3	3.7	105.9
63	78	74	75	71	65	64	71	74	73	71	70	73	70	74	74	80	77	77	87	71	62	63	51	50	104.5	4.2	108.7
64	80	76	75	71	65	66	71	75	73	70	70	73	71	74	75	80	78	78	89	72	63	65	53	51	106.3	4.7	111.0
65	80	78	75	72	65	68	73	75	73	69	72	73	72	74	75	81	78	78	89	72	63	66	53	51	106.4	4.7	111.1
66	80	78	74	72	65	70	75	76	74	69	74	73	73	74	76	82	78	80	91	74	65	67	54	51	107.8	4.6	112.4
67	80	79	74	72	68	74	78	78	73	72	76	74	75	76	77	82	80	81	91	76	69	70	56	51	108.7	4.1	112.8
68	80	78	74	70	68	76	80	78	72	75	76	75	76	76	78	82	80	83	92	77	70	71	57	52	109.6	4.0	113.6
69	81	77	72	68	70	77	81	78	73	76	75	76	76	76	79	82	80	84	92	78	72	73	59	53	110.0	3.6	113.6
70	81	76	72	67	71	78	80	77	74	77	75	76	76	77	81	83	81	85	93	79	74	75	62	54	110.6	3.3	113.9
71	80	75	73	68	74	80	81	76	76	78	77	77	77	78	82	84	82	86	92	80	75	75	63	55	110.7	2.9	113.7
72	81	75	71	69	77	82	82	75	78	78	78	77	77	78	82	84	82	86	91	80	76	75	65	55	110.1	2.6	112.7
73	82	75	71	72	80	84	81	76	79	78	79	78	77	79	83	84	82	88	91	81	78	76	66	57	110.3	2.1	112.4
74	80	75	71	75	82	84	81	78	80	79	79	79	79	79	83	84	82	91	91	83	80	78	69	59	111.4	1.9	113.3
75	81	74	72	76	83	84	80	81	80	81	81	80	80	81	84	84	83	93	92	84	82	80	72	61	112.3	1.8	114.0
76	80	73	75	79	84	84	79	82	80	82	81	81	80	81	85	85	84	95	92	85	84	80	74	63	113.5	2.4	115.9
77	79	73	77	82	84	85	80	83	81	83	81	81	82	82	85	85	84	96	90	85	86	80	76	65	114.1	2.8	116.9
78	78	74	79	83	86	85	80	84	82	83	82	83	82	82	84	85	85	96	89	85	86	81	77	66	114.3	3.1	117.3
79	78	75	80	84	86	85	82	85	82	83	83	83	81	82	83	84	86	97	88	85	87	81	78	67	115.3	3.5	118.8
80	78	75	80	85	86	84	82	85	82	83	83	83	81	83	83	84	89	99	87	86	88	82	79	68	116.7	3.7	120.4

CONTINUED

ONE-THIRD OCTAVE BAND TEST DAY SOUND-PRESSURE LEVEL, DB (RE 0.0002 MICROBARS)

EVENT	CENTER FREQUENCY, HZ													CENTER FREQUENCY, KHZ											PNL(K)	C(K)	PNLT(K)
NO	50	63	80	100	125	160	200	250	315	400	500	630	800	1.	1.25	1.6	2.	2.5	3.15	4.	5.	6.3	8.	10	PNDB	DB	PNDB
81	78	73	80	85	87	84	82	85	82	83	83	83	82	83	83	85	92	99	87	87	88	82	79	69	116.9	3.2	120.2
82	77	73	81	85	86	85	82	85	81	83	82	83	82	83	83	85	93	99	87	88	89	82	79	68	116.7	3.0	119.7
83	76	72	80	85	87	85	79	84	81	83	82	82	81	82	84	85	95	96	86	90	87	81	75	65	115.0	2.5	117.4
84	76	73	78	84	86	85	78	84	81	82	81	82	79	81	84	84	94	94	84	89	85	79	73	62	113.4	1.8	115.2
85	77	74	77	85	86	85	78	83	82	80	80	81	79	80	82	83	93	91	83	88	83	77	70	60	111.7	2.1	113.8
86	79	74	75	84	85	84	79	80	82	79	80	80	78	79	81	81	92	89	81	86	81	75	68	57	110.1	2.3	112.5
87	81	75	72	83	85	84	80	78	81	78	79	79	78	78	79	79	90	87	79	83	78	72	65	55	108.5	2.5	111.0
88	82	74	71	82	84	84	80	77	80	77	78	78	77	78	78	77	89	86	77	81	76	70	62	54	107.5	2.7	110.1
89	83	76	71	81	83	83	81	75	80	77	77	77	76	76	76	76	87	84	75	79	74	68	59	52	105.7	2.6	108.3
90	83	78	73	78	81	83	81	75	78	77	76	76	75	75	75	74	86	82	74	77	72	66	57	52	104.6	2.8	107.3
91	82	80	72	76	79	82	80	76	76	77	75	76	74	74	74	73	85	80	72	76	70	64	55	51	103.4	2.9	106.3
92	81	80	73	74	77	81	81	77	73	76	74	75	74	73	73	72	83	78	70	73	67	62	53	51	101.8	2.9	104.7
93	81	79	74	73	75	80	81	77	71	76	74	75	72	72	72	70	81	75	68	71	65	60	52	51	99.8	2.7	102.6
94	80	79	76	72	72	78	80	76	70	75	74	74	72	71	71	69	79	73	67	70	63	58	51	51	98.8	2.8	101.5
95	81	80	78	73	70	77	78	77	70	73	74	73	71	71	71	68	78	72	66	68	61	57	51	51	97.8	2.8	100.5
96	81	81	79	73	68	74	77	77	70	71	73	72	70	71	71	68	77	71	64	66	60	57	51	51	97.1	2.7	99.8
97	81	80	78	72	67	72	75	76	71	70	73	71	69	70	70	68	77	70	63	64	58	56	51	51	96.4	2.8	99.1
98	80	78	77	72	66	70	74	74	71	69	72	70	69	70	69	67	76	69	63	63	58	56	51	51	95.5	2.7	98.2
99	78	78	76	73	66	67	72	74	72	68	72	69	69	69	67	66	75	68	62	62	57	55	51	51	94.5	2.7	97.2
100	78	77	76	74	67	65	71	74	73	68	72	70	69	69	68	66	75	68	62	62	56	55	50	51	94.6	2.7	97.3
101	78	77	75	74	67	64	69	74	73	68	70	70	69	70	69	66	75	68	61	61	56	55	50	51	94.5	2.7	97.2
102	79	78	76	75	67	63	68	73	73	68	69	70	68	69	69	66	74	67	61	61	56	55	50	51	93.9	2.6	96.6
103	79	78	76	74	67	62	67	73	72	68	67	69	67	68	68	65	73	66	60	60	56	55	50	51	92.8	2.5	95.3
104	79	78	77	73	68	61	66	71	71	68	65	68	66	67	66	64	72	65	60	59	56	55	50	51	92.0	2.5	94.5
105	80	79	75	72	68	60	63	69	71	68	64	67	65	67	65	63	71	64	60	58	55	55	50	51	91.4	2.5	93.9
106	80	79	76	73	68	60	62	67	70	67	63	66	65	66	64	62	70	64	59	58	55	55	50	51	90.8	2.4	93.2
107	81	79	77	75	68	61	61	66	69	67	63	65	65	65	64	61	70	63	58	57	55	55	50	51	90.4	2.4	92.8
108	81	79	77	75	69	62	60	65	69	67	63	64	64	64	63	60	69	62	58	57	55	55	50	51	89.8	2.4	92.2
109	80	79	76	74	69	63	60	63	68	68	63	63	64	63	62	60	68	61	58	57	55	55	50	51	89.1	2.4	91.5
110	79	79	75	75	69	64	59	63	67	67	63	61	63	62	62	59	67	61	57	56	55	55	50	51	88.5	2.3	90.8
111	78	78	75	73	69	63	59	62	65	66	62	61	62	61	60	59	66	60	57	56	55	55	50	51	87.8	2.3	90.1
112	77	76	74	73	70	63	58	61	64	65	62	60	61	60	60	58	65	60	57	56	55	55	50	51	87.3	2.1	89.4
113	78	76	74	73	70	64	58	60	63	65	62	59	61	60	60	58	65	60	57	56	55	55	50	51	87.0	2.0	89.0
114	77	75	73	73	69	65	58	59	62	65	62	59	60	60	60	58	65	59	56	55	55	55	50	51	86.6	2.0	88.7
115	76	73	71	72	68	64	59	58	62	64	63	59	59	60	59	58	64	59	56	55	55	55	50	51	86.1	2.0	88.1
116	75	73	71	71	67	64	59	58	61	64	62	59	58	60	58	57	64	59	56	55	55	55	50	51	85.6	1.9	87.6
117	74	74	71	69	67	64	59	57	61	62	62	59	58	60	58	57	63	58	56	55	55	55	50	51	85.1	1.8	86.9
118	74	74	70	68	67	64	59	57	60	61	62	59	57	59	58	56	62	58	56	55	55	55	50	51	84.6	1.6	86.1
119	74	74	68	68	66	63	59	56	59	61	61	59	57	59	58	56	62	58	56	55	55	55	50	51	84.3	1.6	85.9
120	76	74	68	68	66	63	58	56	59	61	61	58	57	59	58	56	61	58	56	55	55	55	50	51	84.2	1.5	85.7
121	76	75	70	68	65	63	58	56	58	61	60	58	56	58	58	55	61	57	56	55	55	55	50	51	84.0	1.5	85.5
122	75	73	70	67	64	63	58	56	58	61	60	58	56	58	57	55	60	57	56	55	55	55	50	51	83.6	1.5	85.1
123	76	73	71	67	64	62	58	56	57	60	59	58	56	57	56	54	60	57	56	55	55	55	50	51	83.4	1.5	84.9
124	76	73	72	68	64	62	59	56	57	60	59	57	56	57	56	54	60	57	56	55	55	55	50	51	83.3	1.5	84.7
125	76	73	72	67	64	60	59	56	57	60	59	57	56	57	56	54	60	57	56	55	55	55	50	51	83.1	1.5	84.6
126	75	73	72	68	64	61	59	56	57	60	59	57	56	56	56	54	59	57	56	55	55	55	50	51	83.0	1.4	84.5
127	74	74	73	68	63	60	59	56	56	59	58	56	56	56	56	54	59	57	56	55	55	55	50	51	83.0	1.5	84.4
128	74	73	72	69	64	60	58	56	56	59	58	56	56	56	56	53	59	57	56	55	55	55	50	51	82.9	1.4	84.4
129	75	73	73	71	66	63	61	58	58	60	59	57	56	56	56	53	59	57	56	55	55	55	50	51	83.4	1.4	84.8
130	77	74	73	70	66	63	60	58	58	58	58	57	56	56	55	53	59	57	56	55	55	55	50	51	83.2	1.3	84.5
131	73	72	71	69	64	62	59	58	56	56	56	56	55	55	54	53	58	56	55	55	55	55	50	51	82.4	1.2	83.6

CONTINUED

ONE-THIRD OCTAVE BAND TEST DAY SOUND-PRESSURE LEVEL, DB (RE 0.0002 MICROBARS)

	CENTER FREQUENCY, HZ													CENTER FREQUENCY, KHZ													
EVENT NO	50	63	80	100	125	160	200	250	315	400	500	630	800	1.	1.25	1.6	2.	2.5	3.15	4.	5.	6.3	8.	10	PNL(K) PNDB	C(K) DB	PNLT(K) PNDB
132	73	72	70	67	63	62	59	57	56	56	56	56	55	54	54	52	58	56	55	55	55	55	50	51	82.2	1.2	83.4
133	73	73	69	67	63	62	59	57	55	55	56	55	55	54	54	52	58	56	55	55	55	55	50	51	82.1	1.2	83.3
134	72	73	69	66	62	62	59	57	55	55	56	55	55	54	54	52	58	56	55	55	55	55	50	51	82.1	1.2	83.3
135	72	71	68	67	62	63	60	57	55	55	56	55	55	54	54	52	58	56	55	55	55	55	50	51	82.0	1.2	83.2
136	72	70	68	66	61	62	59	57	55	55	56	55	54	54	54	52	58	56	55	55	55	55	50	51	81.8	1.2	83.1
137	72	71	69	65	62	62	59	57	56	55	56	55	54	54	54	52	58	56	55	55	55	55	50	51	81.8	1.2	83.1
138	70	69	69	65	62	62	59	57	56	55	56	55	54	54	54	52	58	56	55	55	55	55	50	51	81.8	1.2	83.1
139	70	69	69	66	62	62	60	58	58	56	56	55	54	55	54	52	58	56	55	55	55	55	50	51	82.0	1.2	83.2
140	70	68	68	65	62	63	61	58	58	57	56	55	54	55	54	52	58	56	55	55	55	55	50	51	82.0	1.2	83.2
141	71	68	67	65	63	63	61	59	58	57	57	56	54	55	54	52	58	56	55	55	55	55	50	51	82.0	1.2	83.3
142	71	67	66	64	62	63	60	59	58	57	57	56	54	56	54	52	58	56	55	55	55	55	50	51	81.9	1.2	83.2
143	69	66	65	65	61	63	60	58	58	57	57	56	54	56	54	52	58	56	55	55	55	55	50	51	81.8	1.2	83.1
144	69	69	66	66	61	62	59	58	57	57	57	55	54	56	54	52	58	56	55	55	55	55	50	51	81.8	1.3	83.1

APPENDIX B

CONCLUDED

HIGHLIGHTS OF FLYOVER NOISE CALCULATIONS –
PNLM, PNLTM, PNLP, AND EPNL

FLIGHT NO.5 ITEM NO.12 STATION NO.10
TEST DAY ATMOSPHERIC CONDITIONS

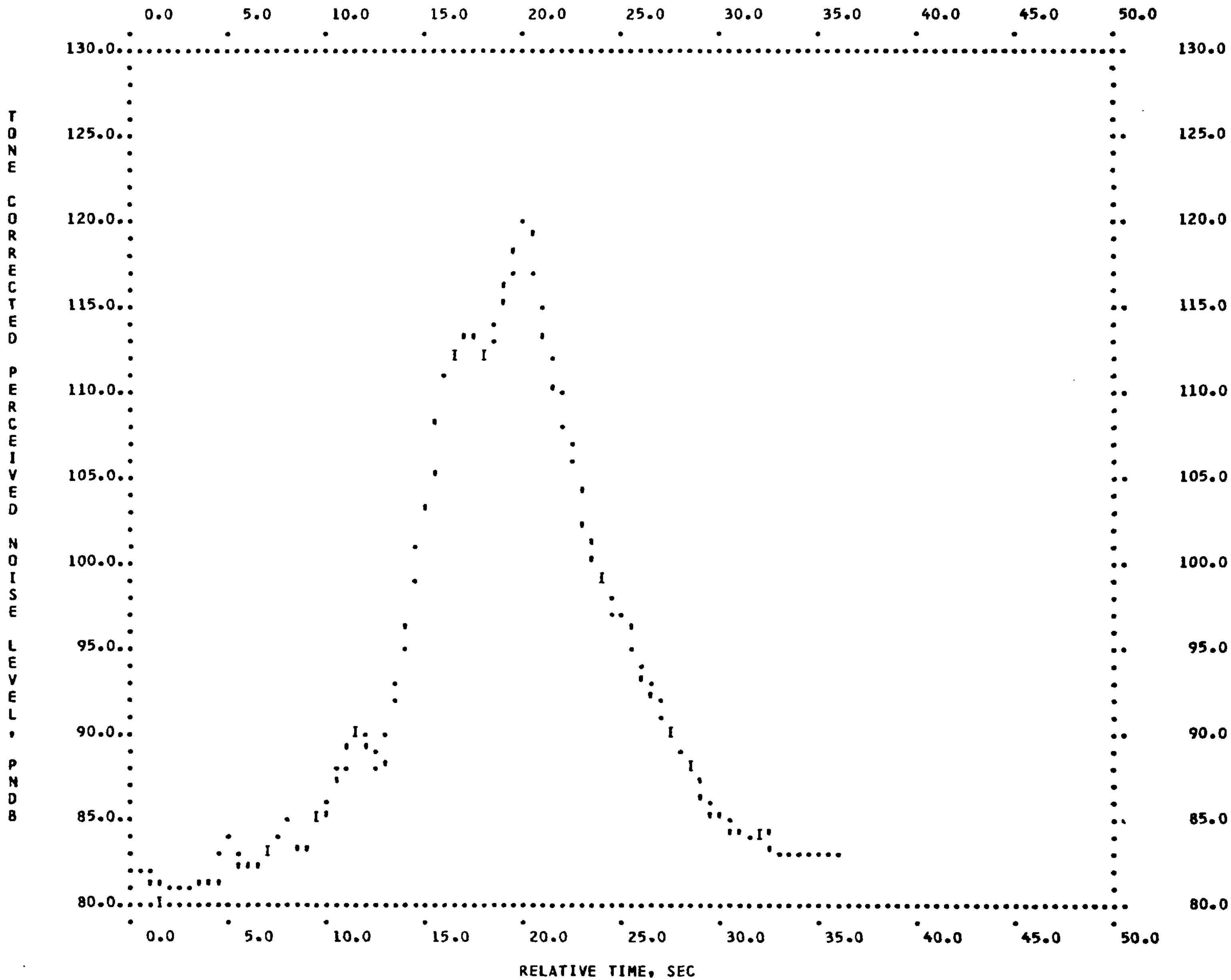
1/3-OCTAVE BAND SPL'S AT TIME OF PNLM (EVENT NO. 81)			1/3-OCTAVE BAND SPL'S AT TIME OF PNLTM (EVENT NO. 80)			PEAK 1/3-OCTAVE BAND SPL'S FOR COMPOSITE PNL		
FREQUENCY, HZ	SPL, DB	NOISINESS, NOYS	FREQUENCY, HZ	SPL, DB	NOISINESS, NOYS	FREQUENCY, HZ	SPL, DB	NOISINESS, NOYS
50	78.0	4.1	50	77.8	4.0	50	82.7	6.5
63	73.2	3.4	63	75.1	4.1	63	80.7	6.9
80	79.8	7.5	80	80.3	7.8	80	81.0	8.3
100	85.4	14.3	100	84.9	13.8	100	85.4	14.3
125	86.6	16.7	125	86.0	16.0	125	87.1	17.3
160	83.9	14.8	160	83.8	14.7	160	85.1	16.1
200	82.2	15.2	200	82.0	15.0	200	82.2	15.2
250	85.5	20.4	250	85.4	20.3	250	85.5	20.4
315	82.2	17.1	315	82.2	17.1	315	82.2	17.1
400	83.1	19.8	400	83.4	20.3	400	83.4	20.3
500	82.8	19.4	500	82.7	19.3	500	82.8	19.4
630	83.4	20.3	630	83.4	20.3	630	83.4	20.3
800	81.7	18.0	800	81.0	17.1	800	81.8	18.1
1000	83.1	19.8	1000	83.1	19.8	1000	83.1	19.8
1250	83.3	23.1	1250	83.2	22.9	1250	84.8	25.6
1600	84.7	33.1	1600	84.4	32.4	1600	84.7	33.1
2000	91.7	61.5	2000	89.1	51.4	2000	94.6	75.1
2500	99.4	119.7	2500	99.4	119.7	2500	99.4	119.7
3150	87.3	55.8	3150	87.3	55.8	3150	92.8	81.5
4000	87.4	56.2	4000	86.3	52.1	4000	89.7	65.9
5000	88.1	55.2	5000	87.8	54.0	5000	88.7	57.5
6300	82.3	34.3	6300	82.1	33.9	6300	82.4	34.6
8000	79.4	22.9	8000	78.9	22.1	8000	79.4	22.9
10000	68.8	9.0	10000	68.4	8.7	10000	68.8	9.0

PNLM = 116.9 PNDB   PNLTM = 120.4 PNDB   PNLP = 117.6 PNDB

INTEGRATION TIME FOR DURATION CORRECTION = 6.00 SECONDS

DURATION CORRECTION FACTOR BY INTEGRATION, D = -6.8 DB

EFFECTIVE PERCEIVED NOISE LEVEL, EPNL = 113.6 EPNDB


TONE CORRECTED PERCEIVED NOISE LEVEL, PNDB
RELATIVE TIME, SEC
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
80.0
85.0
90.0
95.0
100.0
105.0
110.0
115.0
120.0
125.0
130.0

APPENDIX C

SAMPLE FLYOVER NOISE LEVELS FOR REFERENCE-DAY ATMOSPHERIC CONDITIONS

This appendix contains tabulated information similar to that in Appendix B. The SPLs have been corrected for the difference in atmospheric absorption between that which existed on the particular test day and that which would have existed on a reference day with an air temperature of $59^{\circ}F$ and a relative humidity of 70 percent.

The event numbers of Appendix B are replaced in this Appendix by a counter number, C/N. The propagation distance between the microphone and the airplane is shown as DIS in feet. The plot of PNLT(k) versus time illustrates the erroneous PNLTs that were obtained when attempting to apply atmospheric-absorption corrections to the indicated SPLs in Appendix B. Valid duration times, and hence valid duration correction factors, could not be reliably determined.

NASA CONTRACT NAS1-7130. ANALYSIS OF FLYOVER NOISE TESTS AT FRESNO
SEABOARD WORLD AIRLINES DC-8-55 FUSELAGE NO. 242
FOUR UNTREATED PWA JT3D-3B TURBOFAN ENGINES

FLYOVER - LANDING		TEST DATE - 9 FEB 1969	WET BULB - 51.8	DEG.F
REF.FN - 4275	LBS/ENG	FLIGHT NO.- 5	DRY BULB - 64.3	DEG.F
O.H. DIST.- 500	FEET	ITEM NO. - 12	REL.HUM. - 42.0	PERCENT
REF.N1 - 4334	RPM	STA. NO. - 1C	ABS.HUM. - 6.27	GM/M3
EPR - 1.18		LOCATION - L	BAR.PRES. - 29.74	IN.HG
GROSS WT. - 186 000	LBS	REEL NO. - 10-1	WIND SPEED- 2	KNOTS
AIRSPEED - 137	KNOTS	PROG.NO. - E2QD	WIND DIR. - SE	

OVERHEAD COUNTER NO. 6363.50

ONE-THIRD OCTAVE BAND REFERENCE DAY SOUND-PRESSURE LEVEL, DB (RE 0.0002 MICROBARS)
REFERENCE DAY ATMOSPHERIC CONDITIONS
(59.0 DEG.F 70.0 PERCENT)

	CENTER FREQUENCY, HZ													CENTER FREQUENCY, KHZ															
C/N SEC	50	63	80	100	125	160	200	250	315	400	500	630	800	1.	1.25	1.6	2.	2.5	3.15	4.	5.	6.3	8.	10	PNL(K) PNDB	C(K) DB	PNLT(K) PNDB	DIS FEET
6344.75	68	64	65	63	60	60	58	57	56	55	54	54	54	53	53	53	61	62	66	71	75	83	90	107	112.5	0.0	112.5	4663
6345.00	69	66	65	63	61	60	58	57	56	55	55	54	54	53	53	53	61	62	66	71	75	83	90	106	112.3	0.0	112.3	4603
6345.25	70	66	65	63	60	60	58	57	56	55	55	54	54	53	53	53	61	62	65	71	75	83	90	106	111.7	1.0	112.7	4541
6345.50	69	66	65	62	59	59	58	57	56	55	55	54	54	53	53	53	61	62	65	70	74	82	89	105	111.3	0.0	111.3	4478
6345.75	67	65	63	61	59	58	58	57	56	55	55	54	54	53	53	53	61	62	65	70	74	82	89	104	110.6	1.0	111.6	4416
6346.00	67	66	62	61	59	58	57	57	55	55	55	54	54	54	53	54	61	62	65	70	74	82	88	104	110.0	0.0	110.0	4353
6346.25	66	65	63	61	59	59	57	57	55	55	55	54	54	54	53	55	61	62	65	70	73	81	88	103	109.3	0.0	109.3	4291
6346.50	66	64	64	62	59	59	57	57	55	55	55	54	54	54	53	56	60	62	65	69	73	81	88	102	108.7	0.0	108.7	4228
6346.75	66	62	63	61	59	60	57	57	55	55	55	54	54	55	53	56	60	62	65	69	73	80	87	101	108.1	0.0	108.1	4166
6347.00	66	64	63	63	60	60	58	57	56	55	55	54	55	56	54	56	60	61	64	69	72	80	87	101	107.5	0.0	107.5	4104
6347.25	67	67	64	63	62	60	58	57	56	55	55	55	55	56	54	56	60	61	64	69	72	80	86	100	106.9	0.0	106.9	4041
6347.50	67	67	64	63	62	60	59	57	56	55	55	55	56	56	54	57	60	61	64	69	72	79	85	99	106.3	0.0	106.3	3979
6347.75	67	66	64	63	62	61	59	57	57	55	55	56	56	56	54	57	60	61	64	68	72	79	85	98	105.7	0.0	105.7	3916
6348.00	67	65	65	63	62	61	59	58	57	55	55	56	56	56	54	57	60	61	64	68	71	79	84	98	105.0	0.0	105.0	3854
6348.25	66	65	65	64	63	61	60	58	57	55	55	55	56	56	54	58	61	61	64	68	71	78	84	97	104.4	0.0	104.4	3792
6348.50	66	65	65	63	63	62	61	58	56	55	55	55	56	56	54	57	61	61	64	68	71	78	83	96	103.8	0.0	103.8	3729
6348.75	66	64	64	65	62	63	61	58	56	55	55	55	56	56	54	57	61	61	63	67	71	77	83	95	103.2	0.0	103.2	3667
6349.00	66	63	64	66	62	62	61	58	56	55	55	55	56	56	54	57	61	61	63	67	70	77	82	95	102.6	0.0	102.6	3605
6349.25	64	65	64	64	64	63	61	60	56	55	56	56	58	59	55	61	62	61	63	67	70	77	81	94	102.1	0.0	102.1	3542
6349.50	64	65	65	66	64	64	61	59	56	56	57	57	59	60	56	63	62	61	63	67	70	76	81	93	101.7	1.3	103.0	3480
6349.75	65	66	65	66	66	65	61	59	56	57	57	57	60	60	57	63	62	61	63	67	69	76	80	92	101.1	1.2	102.4	3418
6350.00	66	65	66	66	66	65	62	60	56	58	57	57	60	60	57	62	62	61	63	66	69	75	80	92	100.6	0.0	100.6	3356
6350.25	65	66	67	66	65	65	63	61	56	58	58	57	60	58	56	61	61	61	63	66	69	75	79	91	100.0	0.0	100.0	3296
6350.50	66	67	68	66	66	65	63	61	56	58	58	58	59	58	56	59	61	60	62	66	69	75	79	90	99.5	0.0	99.5	3237
6350.75	67	67	69	66	66	66	63	61	56	59	59	59	59	58	55	59	61	60	62	66	68	74	78	89	99.0	0.0	99.0	3178
6351.00	69	70	69	66	66	66	63	60	56	59	59	59	59	58	55	59	61	60	62	66	68	74	78	89	98.5	0.0	98.5	3118
6351.25	70	68	69	66	67	65	62	60	56	58	59	59	59	57	57	58	61	60	62	65	68	74	77	88	98.0	0.0	98.0	3059
6351.50	70	67	68	66	67	65	60	59	56	58	60	61	59	57	59	60	62	60	62	65	68	73	77	87	97.6	0.0	97.6	3000
6351.75	69	66	66	66	67	65	61	58	56	58	60	62	60	59	61	62	64	60	62	65	67	73	76	87	97.2	0.0	97.2	2941

CONTINUED

ONE-THIRD OCTAVE BAND REFERENCE DAY SOUND-PRESSURE LEVEL, DB (RE 0.0002 MICROBARS)

C/N	CENTER FREQUENCY, HZ													CENTER FREQUENCY, KHZ														
SEC	50	63	80	100	125	160	200	250	315	400	500	630	800	1.	1.25	1.6	2.	2.5	3.15	4.	5.	6.3	8.	10	PNL(K) PNDB	C(K) DB	PNLT(K) PNDB	DIS FEET
6352.00	69	64	65	65	65	64	61	58	56	58	60	63	61	60	61	62	64	60	62	65	67	73	76	86	96.7	0.0	96.7	2882
6352.25	69	66	66	66	65	63	60	58	56	59	59	63	60	60	61	62	64	60	62	65	67	72	75	85	96.2	0.0	96.2	2822
6352.50	71	67	67	67	65	64	61	58	56	60	60	63	60	59	61	62	64	60	62	64	67	72	74	84	95.8	1.1	96.9	2763
6352.75	73	69	67	68	67	64	62	58	56	60	60	63	59	59	61	62	63	60	61	64	66	71	74	84	95.3	1.1	96.5	2704
6353.00	73	68	68	68	67	64	62	58	56	60	61	62	58	58	59	60	62	60	61	64	66	71	73	83	94.8	0.0	94.8	2645
6353.25	73	69	67	68	67	64	61	58	57	60	62	62	57	57	57	60	62	60	61	64	66	71	73	82	94.3	0.0	94.3	2586
6353.50	73	67	68	68	67	64	60	57	58	60	63	62	57	58	58	60	62	60	61	64	66	70	72	81	93.9	0.0	93.9	2527
6353.75	71	68	68	68	67	64	60	58	58	60	63	62	57	60	59	62	62	60	61	63	65	70	72	81	93.5	0.0	93.5	2469
6354.00	71	69	68	68	66	64	60	57	58	60	62	62	57	61	59	63	63	61	61	63	65	70	71	80	93.1	1.0	94.2	2410
6354.25	71	69	68	68	67	64	60	57	57	61	62	62	57	61	59	64	63	61	61	63	65	69	71	79	92.8	1.1	93.9	2351
6354.50	72	70	69	69	67	65	60	57	57	60	62	61	57	61	59	64	63	61	61	63	65	69	70	79	92.5	1.1	93.5	2292
6354.75	72	70	70	69	68	64	60	57	57	60	62	61	57	62	59	65	63	61	61	62	64	68	70	78	92.1	1.3	93.4	2234
6355.00	72	70	69	69	68	64	59	57	57	61	62	61	57	62	60	67	64	61	61	62	64	68	69	77	91.9	1.7	93.6	2175
6355.25	73	69	69	69	67	63	59	57	57	62	62	61	57	62	60	68	65	61	61	62	64	68	69	76	91.6	1.9	93.5	2121
6355.50	73	71	69	69	67	64	59	57	58	63	63	61	58	64	60	68	65	62	62	62	64	67	68	76	91.5	1.8	93.3	2066
6355.75	73	70	69	69	66	64	59	57	59	66	65	61	59	67	62	70	68	64	63	62	63	67	68	75	91.7	2.1	93.8	2011
6356.00	73	72	70	70	65	63	59	58	61	67	67	62	61	67	63	70	69	65	64	62	63	67	67	74	91.7	1.9	93.6	1957
6356.25	72	70	70	70	64	64	60	58	62	68	67	62	62	68	64	70	69	66	64	61	63	66	67	74	91.9	1.7	93.6	1902
6356.50	72	69	69	70	66	64	60	58	64	68	67	62	63	68	65	70	69	66	64	61	63	66	66	73	91.7	1.2	93.0	1848
6356.75	72	69	69	70	67	65	59	59	64	69	67	61	63	68	65	69	68	66	65	61	62	66	66	72	91.4	1.2	92.6	1794
6357.00	73	69	69	70	67	65	59	59	64	68	67	61	63	67	65	69	68	65	65	61	62	65	66	72	91.1	1.1	92.2	1740
6357.25	75	72	72	72	67	64	58	61	66	68	66	61	63	67	64	68	67	65	66	61	62	65	65	71	91.3	0.0	91.3	1680
6357.50	77	73	72	72	67	63	59	62	67	68	66	61	63	67	65	69	67	65	66	61	62	65	64	70	91.5	0.0	91.5	1621
6357.75	75	73	72	72	67	64	60	63	67	68	66	62	65	68	67	71	70	67	67	61	61	64	64	70	92.4	0.0	92.4	1561
6358.00	74	73	73	73	69	64	60	64	68	69	67	63	67	68	67	72	71	68	69	63	61	64	63	69	93.4	1.2	94.6	1502
6358.25	74	74	73	71	67	63	61	66	69	69	67	64	68	68	68	74	72	71	71	65	61	64	63	68	94.8	1.2	96.0	1444
6358.50	74	74	73	72	67	63	62	68	70	70	68	64	70	68	69	76	74	71	73	65	61	63	62	67	95.8	1.6	97.5	1385
6358.75	75	74	73	73	68	63	63	69	71	71	68	66	71	69	70	76	74	71	75	67	61	63	62	67	97.1	1.9	99.0	1327
6359.00	76	75	73	72	69	63	65	70	72	71	69	67	71	69	70	76	75	72	78	68	61	63	61	66	98.8	2.6	101.4	1270
6359.25	76	74	73	72	69	63	66	71	72	71	69	68	71	70	71	77	75	73	81	71	62	62	61	65	100.5	3.0	103.4	1213
6359.50	76	73	73	72	68	62	67	71	71	71	68	69	70	73	72	78	76	74	83	71	62	63	60	65	102.0	3.6	105.6	1156
6359.75	75	74	75	73	67	62	69	73	72	71	68	71	70	73	72	79	76	74	83	71	63	64	60	64	102.1	3.4	105.5	1101
6360.00	76	74	75	72	66	63	70	74	73	71	69	72	70	74	74	80	77	77	86	73	65	67	60	63	104.2	3.6	107.8	1046
6360.25	78	74	75	71	65	64	71	74	73	71	70	73	70	74	75	81	78	78	89	74	66	69	60	63	106.3	4.2	110.5	991
6360.50	80	76	75	71	65	66	71	75	73	70	70	73	71	74	75	81	78	79	91	75	67	71	61	63	108.1	4.7	112.8	937
6360.75	80	78	75	72	65	68	73	76	74	69	72	73	72	74	75	81	79	79	91	75	67	71	61	62	108.1	4.7	112.8	884
6361.00	80	78	74	72	65	70	75	76	74	69	74	73	73	74	76	82	79	81	93	77	69	73	61	62	109.5	4.5	114.0	833
6361.25	80	79	74	72	68	74	78	78	73	72	76	74	76	76	78	83	81	82	93	79	72	75	63	61	110.2	4.1	114.3	784
6361.50	80	78	74	70	68	76	80	78	72	75	76	75	76	76	78	83	81	84	94	79	73	76	64	61	111.1	4.0	115.0	738
6361.75	81	77	72	68	70	77	81	78	73	77	75	76	76	76	79	83	81	85	94	80	75	77	65	61	111.4	3.5	114.9	694
6362.00	81	76	72	67	71	78	80	77	74	77	75	76	76	77	81	84	81	86	94	82	77	79	68	62	111.9	3.3	115.2	654
6362.25	80	76	73	68	75	80	81	76	76	78	77	77	77	78	82	84	82	87	94	83	78	79	69	63	111.9	2.9	114.8	617
6362.50	81	75	71	69	77	82	82	75	78	78	78	77	77	78	82	84	82	87	92	83	78	79	70	63	111.3	2.5	113.8	586
6362.75	82	75	71	72	80	84	81	76	79	78	79	78	78	79	83	84	83	89	92	83	80	80	71	64	111.4	2.1	113.5	560
6363.00	80	75	71	75	82	84	81	78	80	79	79	79	79	79	84	84	83	92	93	85	83	82	74	66	112.5	1.8	114.3	541
6363.25	81	74	72	76	83	84	80	81	81	81	81	80	80	81	84	84	84	94	93	86	85	83	77	68	113.3	1.7	115.0	528
6363.50	80	73	75	79	84	84	79	82	81	82	81	81	80	81	85	85	84	96	93	87	86	83	79	70	114.4	2.3	116.7	524
6363.75	80	73	77	82	84	85	80	83	81	83	81	82	82	82	85	85	85	96	91	87	88	84	80	71	115.0	2.8	117.8	521
6364.00	78	74	79	83	86	85	80	84	82	83	82	83	82	82	84	85	85	97	90	86	88	84	82	72	115.2	3.0	118.2	525
6364.25	78	75	80	84	86	85	82	85	82	83	83	83	82	82	83	85	87	98	89	87	89	84	83	74	116.2	3.5	119.7	535
6364.50	78	75	80	85	86	84	82	85	82	83	83	83	81	83	83	85	90	100	88	88	90	85	84	75	117.6	3.7	121.3	551

CONTINUED

ONE-THIRD OCTAVE BAND REFERENCE DAY SOUND-PRESSURE LEVEL, DB (RE 0.0002 MICROBARS)

	CENTER FREQUENCY, HZ													CENTER FREQUENCY, KHZ															
C/N SEC	50	63	80	100	125	160	200	250	315	400	500	630	800	1.	1.25	1.6	2.	2.5	3.15	4.	5.	6.3	8.	10	PNL(K) PNDB	C(K) DB	PNLT(K) PNDB	DIS FEET
6364.75	78	73	80	85	87	84	82	86	82	83	83	83	82	83	83	85	92	100	89	89	91	86	85	76	117.9	3.2	121.1	573
6365.00	77	73	81	85	87	85	82	86	82	83	82	83	82	83	83	85	94	100	88	90	91	86	84	75	117.7	3.0	120.7	599
6365.25	76	72	80	85	87	85	79	84	81	83	82	82	81	83	84	85	95	97	87	92	90	85	81	73	116.0	2.4	118.4	635
6365.50	76	73	78	84	86	85	78	84	82	82	81	82	80	81	84	84	95	95	86	92	88	83	79	71	114.6	2.3	116.8	675
6365.75	77	74	77	85	86	85	78	83	82	80	80	81	79	80	82	83	94	92	85	91	86	82	77	68	112.8	2.1	115.0	718
6366.00	79	74	75	84	85	84	79	80	82	79	80	80	79	80	81	81	93	90	83	88	84	80	75	67	111.2	2.3	113.5	764
6366.25	81	75	72	83	85	84	80	78	81	78	79	79	78	78	79	79	91	88	80	86	82	77	72	65	109.6	2.4	112.0	812
6366.50	82	75	71	82	84	84	80	77	80	77	78	78	77	78	78	78	90	87	79	84	80	75	70	64	108.6	2.6	111.2	862
6366.75	83	76	71	81	83	83	81	76	80	77	77	77	76	76	76	76	88	85	77	83	78	73	67	64	106.9	2.5	109.4	913
6367.00	83	78	73	78	81	83	81	75	78	77	76	76	75	75	75	75	87	83	76	81	76	72	66	64	105.8	2.7	108.5	966
6367.25	82	80	73	76	80	82	80	76	76	77	75	76	74	74	74	73	86	82	74	79	74	70	64	64	104.7	2.8	107.5	1020
6367.50	81	80	73	74	77	81	81	77	74	77	74	76	74	73	73	72	84	79	73	77	72	68	63	64	103.1	2.9	106.0	1075
6367.75	81	79	74	73	75	80	81	77	71	77	74	75	72	72	72	70	82	77	71	75	70	67	62	65	101.2	2.7	103.9	1131
6368.00	80	79	76	72	72	78	80	76	70	75	74	75	72	72	72	70	80	75	70	74	68	66	62	65	100.2	2.7	102.9	1187
6368.25	81	80	78	73	70	77	78	77	70	73	74	73	71	71	71	69	79	73	69	72	67	65	62	66	99.3	2.7	102.0	1244
6368.50	82	81	80	73	68	74	77	77	71	72	73	72	70	71	71	69	79	72	67	71	65	65	62	67	98.6	2.7	101.3	1301
6368.75	82	80	78	72	67	72	75	76	71	70	73	71	70	70	70	68	78	72	66	69	64	64	63	68	98.0	2.7	100.7	1359
6369.00	80	78	77	72	66	70	74	74	71	69	73	70	69	70	69	68	77	71	66	68	64	65	63	68	97.3	2.7	99.9	1417
6369.25	79	78	76	73	66	67	72	74	72	68	72	69	69	69	68	67	76	70	65	67	63	65	64	69	96.4	2.7	99.1	1476
6369.50	78	77	76	74	67	65	71	74	73	68	72	70	69	70	69	67	76	70	65	67	63	65	64	70	96.5	2.7	99.2	1535
6369.75	78	77	75	74	67	64	69	74	73	68	70	71	69	70	69	67	76	70	65	67	63	65	65	70	96.5	2.7	99.2	1594
6370.00	79	78	76	75	67	63	68	73	73	69	69	71	68	69	69	67	76	69	64	67	63	65	65	71	96.1	2.6	98.7	1654
6370.25	79	78	77	74	67	62	67	73	72	68	67	70	67	68	68	66	74	68	64	66	63	66	66	72	95.2	2.4	97.6	1711
6370.50	79	78	77	73	68	61	66	71	71	68	65	68	66	67	66	65	73	67	64	65	63	66	66	73	94.5	2.4	96.9	1769
6370.75	80	79	76	72	68	60	63	69	71	68	64	67	66	67	65	64	73	67	64	65	63	66	67	73	94.1	2.5	96.5	1827
6371.00	80	80	76	73	68	60	62	67	70	68	63	66	65	66	64	63	72	66	63	65	63	67	67	74	93.6	2.3	96.0	1885
6371.25	81	79	77	75	69	61	61	66	69	67	63	65	65	66	64	62	71	66	63	64	64	67	68	75	93.3	2.4	95.7	1943
6371.50	81	80	77	75	69	62	60	65	69	67	63	64	65	64	63	61	70	65	62	64	64	67	68	75	93.0	2.4	95.4	2001
6371.75	80	79	76	74	69	63	60	64	68	68	63	63	64	63	63	60	69	64	62	64	64	68	69	76	93.0	2.3	95.3	2059
6372.00	79	79	75	75	69	64	59	63	67	67	63	62	63	62	62	60	69	63	62	63	64	68	69	77	93.0	2.3	95.3	2117
6372.25	78	78	76	73	69	63	59	62	65	66	62	61	62	61	61	60	68	63	62	63	64	69	70	78	93.1	2.3	95.3	2176
6372.50	77	76	74	73	70	63	58	61	64	66	62	60	61	61	60	59	67	63	62	63	65	69	70	78	93.2	2.1	95.3	2235
6372.75	78	76	74	73	70	64	58	60	64	65	62	59	61	60	60	59	67	63	62	64	65	69	71	79	93.5	2.0	95.5	2293
6373.00	77	75	73	73	69	65	58	59	63	65	62	59	60	60	60	59	67	62	62	64	65	70	72	80	93.7	2.0	95.7	2352
6373.25	76	74	71	72	68	64	59	58	62	64	63	59	59	60	59	59	66	62	62	64	65	70	72	80	93.9	1.9	95.9	2411
6373.50	75	73	71	71	68	64	59	58	61	64	63	59	58	60	59	58	66	62	62	64	65	70	72	81	94.2	1.9	96.0	2470
6373.75	74	74	71	69	67	64	59	57	61	62	62	59	58	60	59	58	65	62	62	64	66	71	73	82	94.5	1.7	96.2	2528
6374.00	74	74	70	68	67	64	59	57	60	61	62	59	58	60	59	58	64	61	62	64	66	71	73	83	94.8	1.5	96.3	2587
6374.25	74	74	69	68	66	63	59	57	59	61	62	59	57	59	58	57	64	61	62	64	66	71	74	83	95.2	1.5	96.7	2646
6374.50	76	74	68	68	66	63	58	56	59	61	61	58	57	59	58	57	63	61	62	64	67	72	74	84	95.5	1.5	97.0	2705
6374.75	76	75	70	68	65	63	58	56	58	61	60	58	57	59	58	56	63	61	62	65	67	72	75	85	96.0	1.5	97.5	2765
6375.00	75	73	70	67	64	63	58	56	58	61	60	58	56	58	58	56	63	61	62	65	67	73	76	85	96.4	1.5	97.8	2824
6375.25	76	73	71	67	64	62	58	56	57	60	59	58	56	57	57	55	62	61	62	65	67	73	76	86	96.8	1.5	98.3	2885
6375.50	76	73	72	68	64	62	59	56	57	60	59	58	56	57	57	55	62	61	62	65	68	73	77	87	97.3	1.4	98.7	2947
6375.75	76	73	72	67	64	60	59	56	57	60	59	57	56	57	57	55	62	61	62	65	68	74	77	88	97.9	1.4	99.3	3009
6376.00	75	73	72	68	64	61	59	56	57	60	59	57	56	56	57	55	62	61	62	66	68	74	78	89	98.4	1.4	99.7	3071
6376.25	74	74	73	68	64	60	59	56	57	59	58	57	56	56	56	55	62	61	62	66	68	74	78	89	98.9	1.4	100.3	3132
6376.50	74	74	72	69	64	60	58	56	56	59	58	57	56	56	56	55	62	61	63	66	69	75	79	90	99.4	1.4	100.8	3194
6376.75	75	73	73	71	66	63	61	58	58	61	60	57	57	56	56	55	62	61	63	66	69	75	79	91	100.1	1.3	101.4	3256
6377.00	77	74	73	70	66	63	60	58	58	59	58	57	57	56	56	55	61	61	63	66	69	76	80	91	100.6	1.2	101.9	3318
6377.25	74	72	72	69	64	62	59	58	56	56	57	56	56	55	55	54	61	61	63	67	69	76	81	92	101.1	1.2	102.2	3380

CONTINUED

ONE-THIRD OCTAVE BAND REFERENCE DAY SOUND-PRESSURE LEVEL, DB (RE 0.0002 MICROBARS)

C/N	CENTER FREQUENCY, HZ													CENTER FREQUENCY, KHZ												PNL(K)	C(K)	PNLT(K)	DIS
SEC	50	63	80	100	125	160	200	250	315	400	500	630	800	1.	1.25	1.6	2.	2.5	3.15	4.	5.	6.3	8.	10	PNDB	DB	PNDB	FEET
6377.50	73	73	70	67	63	62	59	57	56	56	56	56	55	55	55	54	61	61	63	67	70	76	81	93	101.6	1.1	102.7	3442
6377.75	73	74	69	67	63	62	59	57	56	56	56	56	55	55	55	54	61	61	63	67	70	77	82	94	102.1	1.1	103.2	3504
6378.00	72	73	69	66	63	62	59	57	56	55	56	56	55	55	55	54	61	61	63	67	70	77	82	95	102.7	1.1	103.8	3566
6378.25	72	71	68	67	62	63	60	57	56	55	56	55	55	55	55	54	61	61	63	68	70	78	83	95	103.3	1.2	104.5	3628
6378.50	72	70	68	66	61	62	59	57	56	55	56	55	55	55	55	54	61	61	64	68	71	78	83	96	103.9	1.2	105.0	3690
6378.75	72	71	69	65	62	62	59	57	56	55	56	55	55	55	55	54	61	61	64	68	71	78	84	97	104.4	1.2	105.6	3752
6379.00	71	70	70	65	62	62	59	57	56	55	56	55	54	55	55	54	61	61	64	68	71	79	84	98	105.0	1.2	106.2	3814
6379.25	70	69	69	66	62	62	60	58	58	56	56	55	55	55	55	54	61	61	64	68	71	79	85	98	105.7	1.1	106.8	3876
6379.50	70	68	68	65	62	63	61	58	58	57	57	56	54	55	55	54	61	61	64	69	72	79	86	99	106.3	1.1	107.4	3938
6379.75	71	68	67	65	63	63	61	59	58	58	57	56	55	55	55	54	61	61	64	69	72	80	86	100	106.9	1.1	108.1	4000
6380.00	71	67	66	64	62	63	60	59	58	58	57	56	55	56	55	54	61	62	64	69	72	80	87	101	107.6	1.1	108.7	4062
6380.25	69	66	66	65	61	63	60	56	58	57	57	56	55	56	55	54	61	62	64	69	73	81	87	101	108.2	1.1	109.3	4124
6380.50	69	69	66	66	61	62	59	58	58	57	57	55	55	56	55	54	61	62	65	69	73	81	88	102	108.9	1.2	110.1	4187

CONCLUDED

HIGHLIGHTS OF FLYOVER NOISE CALCULATIONS - PNLM, PNLTM, PNLP, AND EPNL

FLIGHT NO.

REFERENCE DAY ATMOSPHERIC CONDITIONS
(59.0 DEG.F 70.0 PERCENT)

1/3-OCTAVE BAND SPL'S AT TIME OF PNLM (COUNTER NO.6364.75)			1/3-OCTAVE BAND SPL'S AT TIME OF PNLTM (COUNTER NO.6364.50)			PEAK 1/3-OCTAVE BAND SPL'S FOR COMPOSITE PNL		
FREQUENCY, HZ	SPL, DB	NOISINESS, NOYS	FREQUENCY, HZ	SPL, DB	NOISINESS, NOYS	FREQUENCY, HZ	SPL, DB	NOISINESS, NOYS
50	78.0	4.1	50	77.8	4.0	50	82.7	6.5
63	73.2	3.4	63	75.1	4.1	63	80.7	6.9
80	79.8	7.5	80	80.3	7.9	80	81.0	8.3
100	85.4	14.3	100	84.9	13.8	100	85.4	14.3
125	86.6	16.7	125	86.0	16.0	125	87.1	17.3
160	83.9	14.8	160	83.8	14.7	160	85.1	16.1
200	82.2	15.2	200	82.0	15.0	200	82.2	15.2
250	85.5	20.4	250	85.4	20.3	250	85.5	20.4
315	82.2	17.1	315	82.2	17.1	315	82.2	17.1
400	83.1	19.9	400	83.4	20.3	400	83.4	20.3
500	82.8	19.5	500	82.7	19.3	500	82.8	19.5
630	83.4	20.3	630	83.4	20.3	630	83.4	20.3
800	81.7	18.0	800	81.0	17.2	800	81.8	18.2
1000	83.2	19.9	1000	83.2	19.9	1000	83.2	19.9
1250	83.4	23.3	1250	83.3	23.1	1250	84.9	25.8
1600	85.0	33.7	1600	84.7	33.0	1600	85.0	33.7
2000	92.2	63.4	2000	89.5	53.0	2000	95.1	77.8
2500	100.1	126.0	2500	100.1	125.7	2500	100.1	126.0
3150	88.5	60.8	3150	88.5	60.6	3150	94.2	89.9
4000	89.4	64.5	4000	88.2	59.5	4000	91.9	76.7
5000	90.6	65.4	5000	90.2	63.7	5000	91.3	68.7
6300	85.8	43.9	6300	85.5	42.9	6300	86.1	44.7
8000	84.5	32.7	8000	83.8	31.1	8000	90.2	48.3
10000	75.8	14.6	10000	75.2	13.9	10000	106.6	121.5

PNLM = 117.9 PNDB

PNLTM = 121.3 PNDB

PNLP = 119.7 PNDB

INTEGRATION TIME FOR DURATION CORRECTION = 20.75 SECONDS

DURATION CORRECTION FACTOR BY INTEGRATION, D = -6.2 DB

EFFECTIVE PERCEIVED NOISE LEVEL, EPNL = 115.1 EPNDB

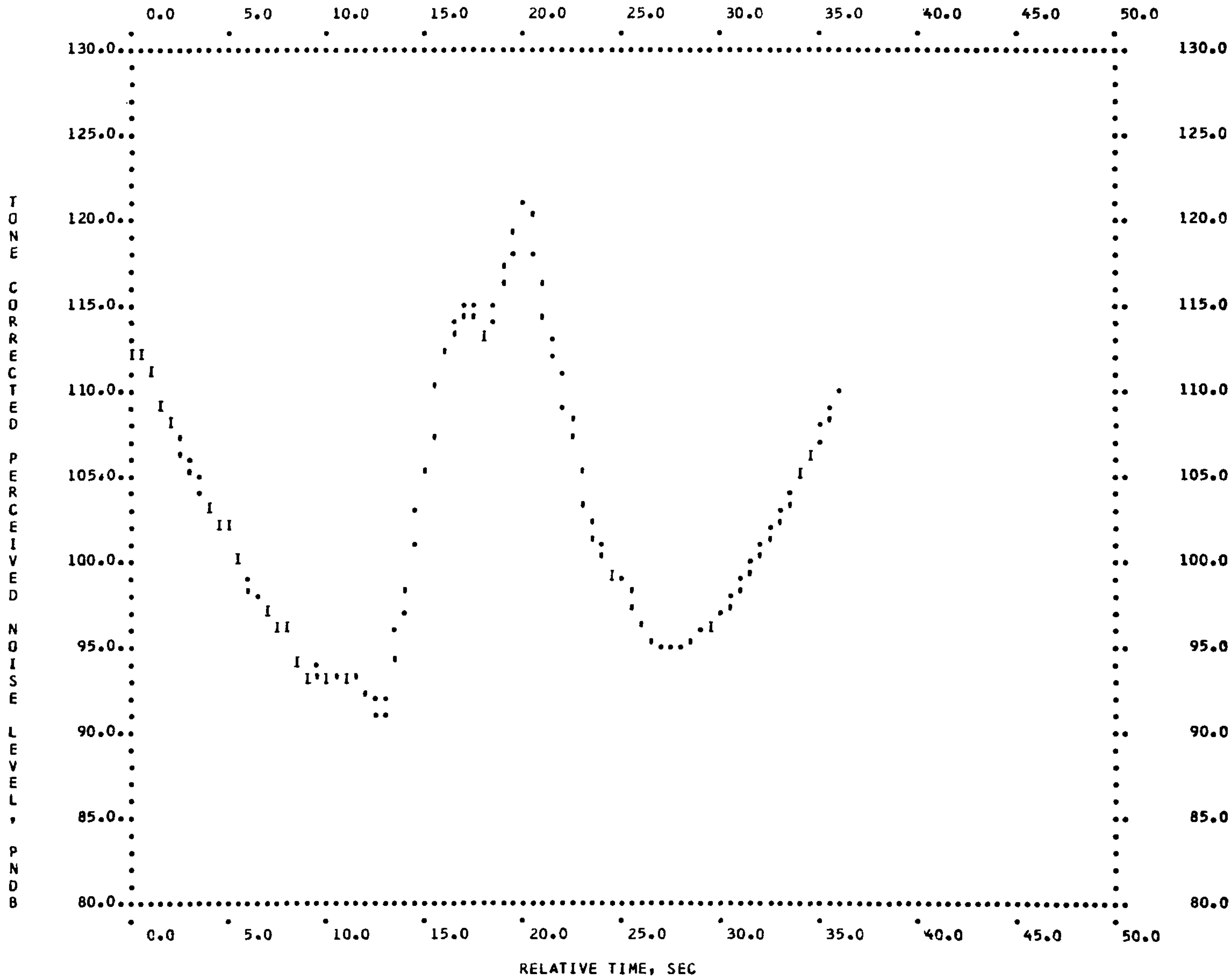

0.0 5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0 45.0 50.0
130.0
125.0
120.0
115.0
110.0
105.0
100.0
95.0
90.0
85.0
80.0
TONE CORRECTED PERCEIVED NOISE LEVEL, PNDB
RELATIVE TIME, SEC

TABLE I. – NACELLE CHANGES REQUIRED BY RETROFIT DESIGN

Items changed	Items unchanged
Inlet cowl and centerbody	Engine mounts (fore and aft)
Fan exhaust ducts	Primary reverser and fairing
Fan air reverser	Primary nozzle and fairing
Engine power controls	Pylon structure
Engine access doors	Pylon piping and electrical systems
Engine piping (moderate revision)	Pylon-nacelle interfaces
Hydraulic system (moderate revision)	Cockpit controls and instruments
Pneumatic system (moderate revision)	

TABLE II. – DUCT-LINING COMPONENTS

Location	Impervious backing sheet	Nominal flow resistance of nominal 0.040-in. thick porous fibermetal sheets, cgs rayls	Depth of air-filled cavities behind porous fibermetal surfaces,[a] in.
Inlet duct			
Cowl	Aluminum	10	0.75
Centerbody	Aluminum	10	0.75
Ring	Steel	10	0.5
Fan-exhaust ducts			
Inboard wall	Titanium	8	0.5
Outboard wall	Aluminum	8	0.75
Splitters	Steel	8	0.5

[a]Porous surfaces are supported by heat-resistant phenolic-coated fiberglass honeycomb with 0.75-in. cells.

TABLE III. – CHANGES IN WEIGHT OF NACELLE COMPONENTS

Item	Weight change, lb
Inlet duct and concentric ring	+136
Inlet centerbody	+10
Fan exhaust ducts	+224
Fan exhaust reversers	–287
Total nacelle weight change	+ 83 lb

TABLE IV. – INSTRUMENTATION INSTALLED IN THE TEST AIRPLANE

System	Units	Range low/high	Manufacturer's Tolerance (Uncorrected readings)
Airspeed System			
Captain's	Knots	50/450	±2 Knots
First officer's	Knots	50/450	±2 Knots
Trail cone	Knots	50/450	±2 Knots
Mach meter	Mach	0.3/1.0	±0.005 Mach
Altimeters			
Captain's	Feet	–1000/45 000	±20 Feet
First officer's	Feet	–1000/45 000	±20 Feet
Trail cone	Feet	–1000/45 000	±20 Feet
Radio (receiver + indicator)	Feet	0/500	±4 Feet
Engine Fuel Flow			
Mass-flow rate	Pounds/hour	0/12 000	±0.7% of reading
Volumetric-flow rate	Counts/sec	0/999 999	±1 Count/sec
Engine Rotor Speed			
Low-compressor speed (N_1)	% rpm	0/110	±1 Percent
High-compressor speed (N_2)	% rpm	0/110	±1 Percent
Temperatures			
Ram-air temperature	°C	–60/+60	±0.3°C
Static-air temperature	°C	–100/+50	±2°C
Exhaust-gas temperature	°C	0/1200	±2°C
Fuel temp at volumetric flow	°F	–100/+500	±0.5°F
Total Pressure			
Engine primary exhaust	In. Hg	0/100	±0.11 In. Hg
Engine pressure ratio (EPR)	none	0.5/2.5	±0.015 Units
Engine Inlet Total Pressure Engine No. 2	In. Hg	0/100	±0.03 In. Hg
Miscellaneous			
Instrument correlation counter	Seconds	0/99 000	N/A
Fuel quantity	Pounds	N/A	±2% of reading
Synchronization system	On-Off	N/A	N/A
Intercompressor bleed	On-Off	N/A	N/A
Blowaway jet (existing-nacelle airplane only)	On-Off	N/A	N/A

Note: Camera recording rates (photo recorder and cockpit) were: 1/5, 1/2, 1, 2, 5, 10 and 16 (cine) frames per second.

Oscillograph recording speeds were: 0.1 and 1.0 in./sec.

TABLE V. – ACOUSTICAL DIFFERENCES BETWEEN STATIC-TEST AND FLIGHT-TEST INLET DUCTS

Inlet parameter that was changed	Static-test inlet	Flight-test inlet	Reason for change
Number of struts supporting ring-vane	10: two at each of five locations	8: two at each of four locations	P&WA recommendation
Number of longitudinal splices in fibermetal	2	3	Ease of fabrication
Profile of cowl at inlet lip	Vertical: (body of revolution)	Canted forward 4 degrees	Required for flight
Backing sheet for duct lining	0.25-in.-thick fiberglass laminate	0.06-in.-thick aluminum	Reduce weight of flight nacelle
Outer nacelle wall of cowl	None	0.08-in.-thick aluminum	Required for flight
Honeycomb support	No drainage grooves	Drainage groves	Required for flight

TABLE VI. – FLIGHT CONDITIONS FOR FLYOVER NOISE TESTS

Test item No.	Flight operation	Nominal gross weight, lb	Nominal thrust, lb/eng	Nominal airspeed, kn
1	Takeoff	300 000	Takeoff	Static to 197
2	Simulated takeoff	295 000	11 000	240
3	Simulated takeoff	245 000	9000	220
4	Landing	240 000	6100	149
5	Takeoff	235 000	Takeoff	Static to 180
6	Simulated takeoff	230 000	11 000	210
7	Simulated takeoff	225 000	9000	200
8	Landing	205 000	5150	137
9	Takeoff	200 000	Takeoff	Static to 180
10	Simulated takeoff	195 000	11 000	180
11	Simulated takeoff	190 000	9000	180
12	Landing	185 000	4600	131

TABLE VII. – TYPICAL SOUND STATION EQUIPMENT

Component	Function	Instrument error
1/2 in. condenser microphone	Acoustical transducer	±0.2 dB
1/2 in. to 1 in. microphone adaptor	Equipment compatibility	–
Sound level meter	Variable gain pre-amplifier	±0.2 dB
Tripod w/extension	Sound level meter support	–
Magnetic tape recorder	Sound recorder	±0.3 dB
Headset	Recorder monitor	–
Pistonphone	Reference sound pressure level	±0.2 dB
Camera	Aircraft height determination with time-correlation trigger	±10 percent
Synchronizing-tone generator	Time correlation tone to station recorder	–
Encoder-Oscillator	Time correlation tone to aircraft	–
VHF radio	Voice communication with, and correlation-tone transmission to, aircraft (at stations 1, 2, 4, 6, 7 and 8)	–
FM radio	Ground-to-ground communication	–
AM radio	Ground-to-ground and air communication	–
Stopwatch	Time correlation via VHF radio	±0.02 sec
Windmeter	Wind speed measurement	±1 mile per hour
Psychrometer	Dry and wet bulb temperature measurement	±0.5°F

TABLE VIII. – LIMITS ON ATMOSPHERIC CONDITIONS FOR FLYOVER NOISE TESTING

Parameter		Desired range	Maximum range
Vertical wind gradient, kn/1000 ft		0 to 3	0 to 11
Deviation of vertical temperature gradient from standard gradient, °F/1000 ft		±2	(a)
Surface wind speed, kn		0 to 10	0 to 15
Surface temperature, °F		49 to 79	35 to 95
	Surface temp., °F		
Surface relative humidity at corresponding surface temperatures, percent	35	–	85 to 90
	45	83 to 90	66 to 90
	55	65 to 90	52 to 90
	65	51 to 90	42 to 90
	75	42 to 90	33 to 90
	85	34 to 90	27 to 90
	95	–	22 to 90

(a)Through extremely undesirable, isothermal conditions or a slight temperature/humidity inversion could be tolerated if the thickness of the adverse conditions were small.

TABLE IX. – DESIRED AND AVERAGE TEST VALUES OF ENGINE AND AIRPLANE CONDITIONS DURING FLYOVER NOISE TESTS

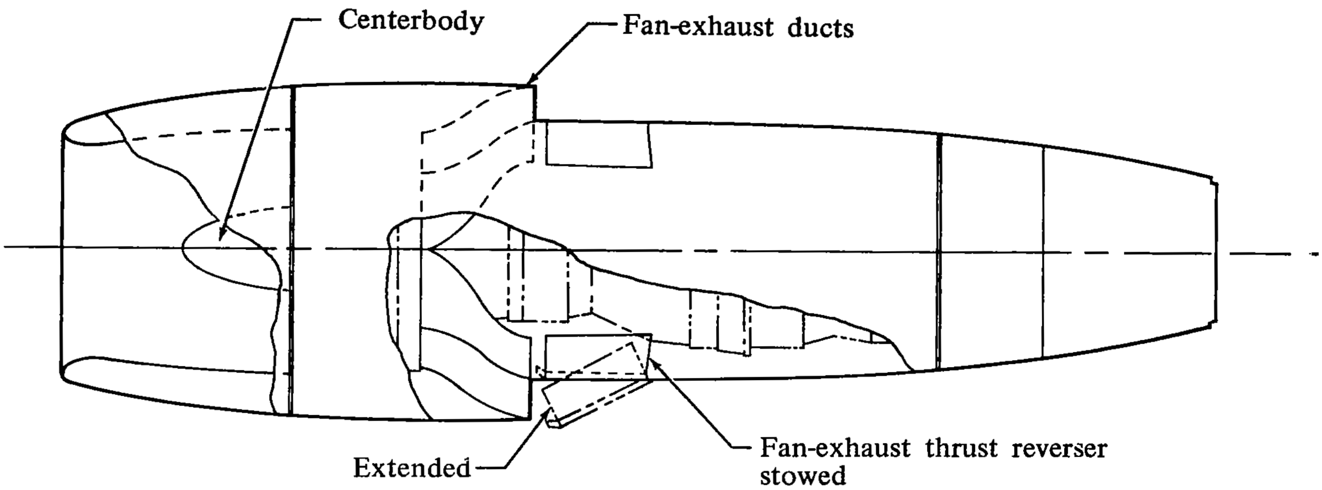
Test item No.	True airspeed, kn			Referred low-pressure rotor speed, rpm		
	Desired condition	Existing-nacelle tests	Modified-nacelle tests	Desired condition	Existing-nacelle tests	Modified-nacelle tests
1	Static to 197	Static to 220	Static to 220	6620	6540	6420
5	Static to 180	Static to 200	Static to 200	6620	6570	6440
9	Static to 180	Static to 195	Static to 195	6620	6590	6460
2	240	245	245	5880	5900	5890
6	210	215	210	5880	5860	5930
10	180	190	190	5880	5880	5930
3	220	225	225	5505	5520	5540
7	200	205	205	5505	5500	5550
11	180	185	185	5505	5510	5570
4	149	155	160	4840	4705	4730
8	137	140	150	4570	4500	4400
12	131	131	135	4380	4290	4150

TABLE X. – LANDING NOISE REDUCTIONS AT 370-FT HEIGHT UNDER A 3-DEGREE LANDING FLIGHT PATH

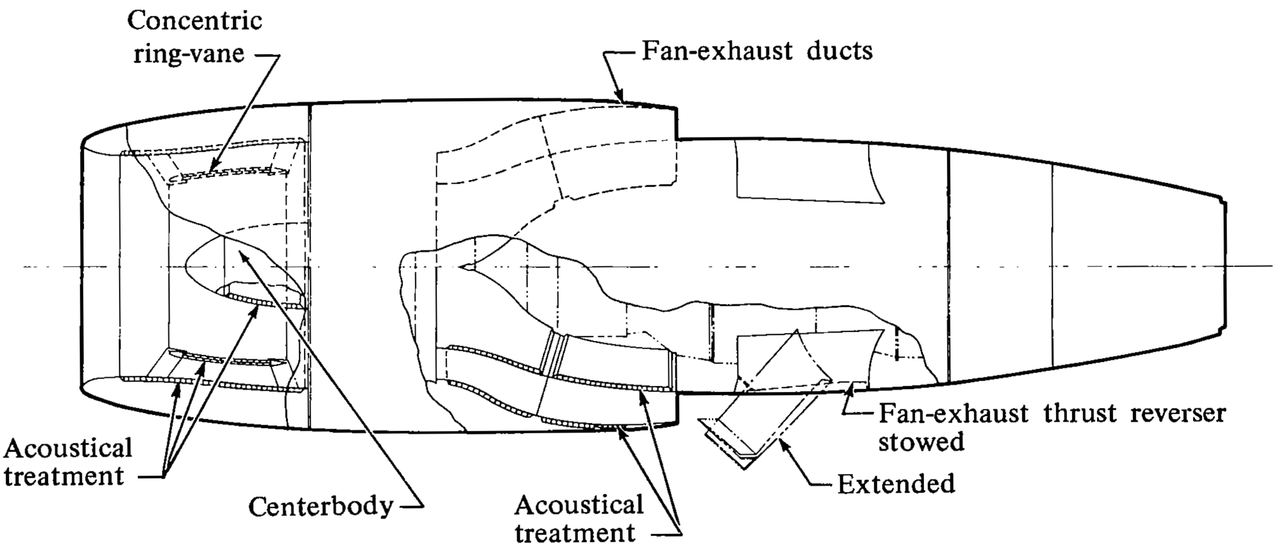
Landing weight, lb	ΔEPNL, EPNdB	Reference-day ΔPNLM, PNdB
240 000	10.5	9
180 000	12	10

TABLE XI. – TAKEOFF NOISE REDUCTIONS

Takeoff weight, lb	Reduction in EPNL under flight path at 3.5 n. mi. from brake release, EPNdB		Reduction in maximum EPNL along 1500-ft sideline, EPNdB
	Rated takeoff thrust	Thrust for 6% climb gradient	
325 000	3.5	5.5	3
≈240 000 (2500 n. mi. range)	1.5	9	3

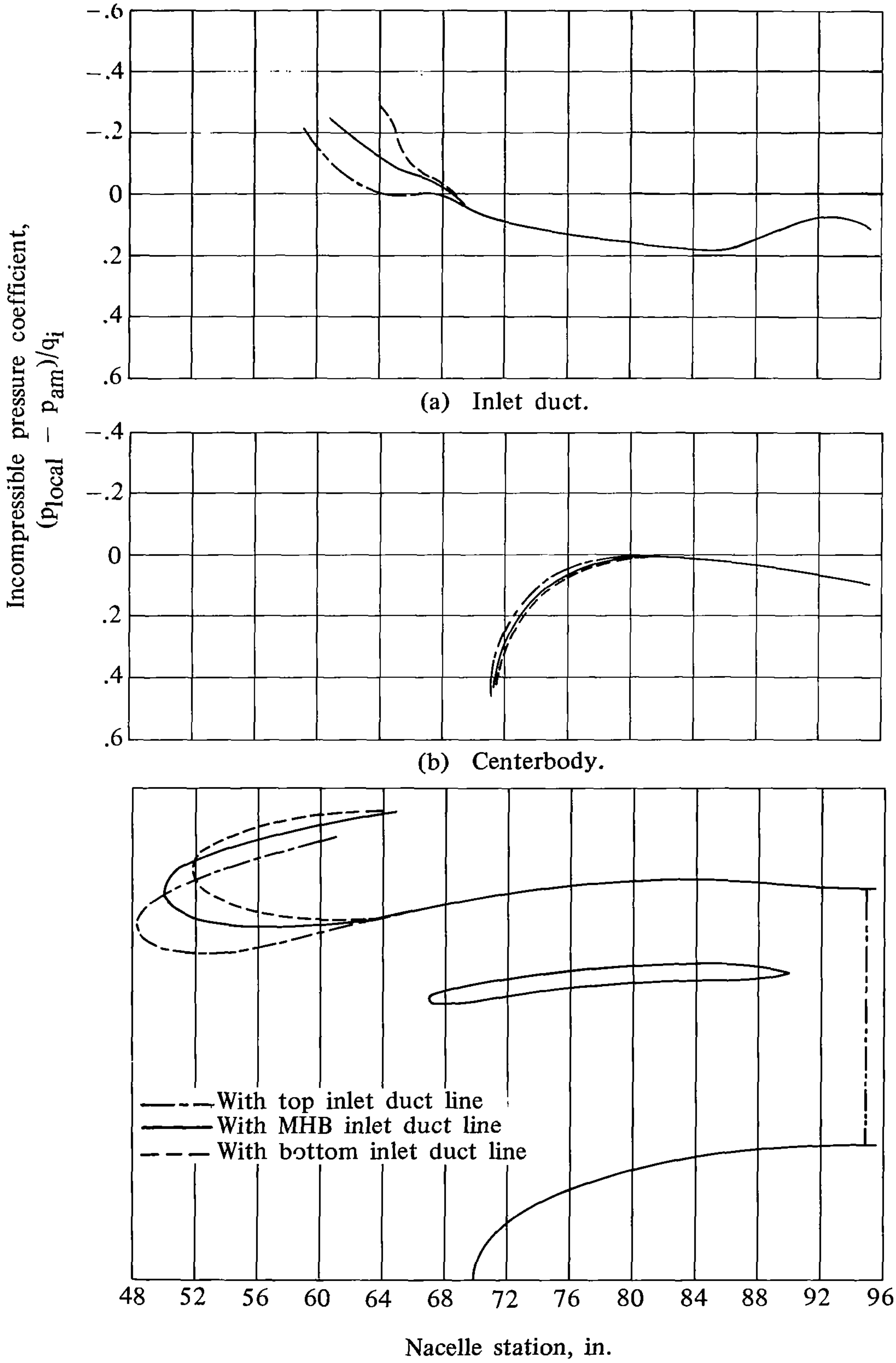


(a) Existing nacelle.



(b) Modified (retrofit) nacelle.

Figure 1. – Plan view of existing and modified (retrofit) nacelle design.

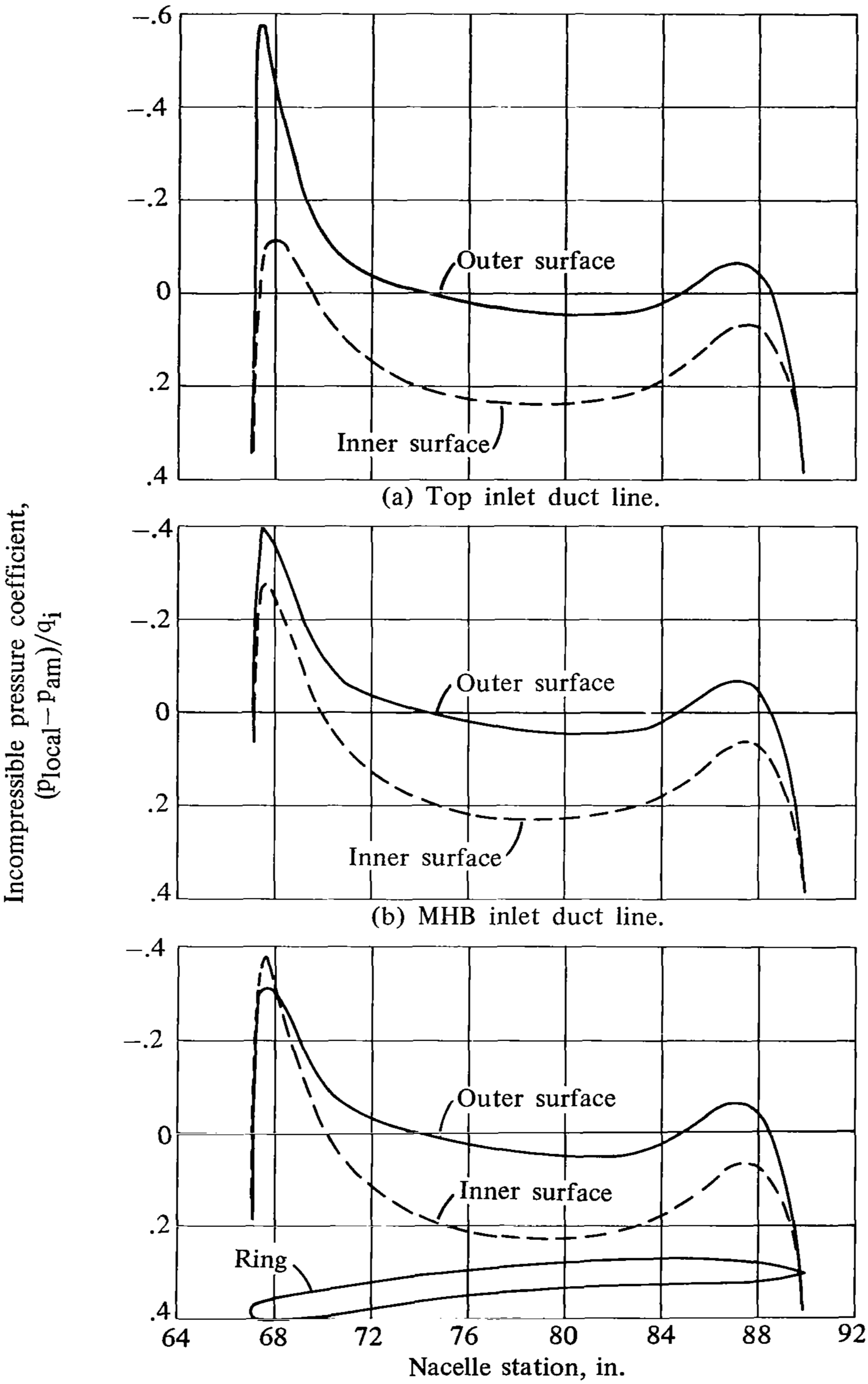


(a) Inlet duct.

(b) Centerbody.

(c) Selected axisymmetric bodies.

Figure 2. – Predicted pressure coefficients for walls of inlet duct and centerbody for selected axisymmetric bodies of the modified inlet.



(c) Bottom inlet duct line.

Figure 3. – Predicted pressure coefficients for the duct lines of the concentric ring of the modified inlet duct.

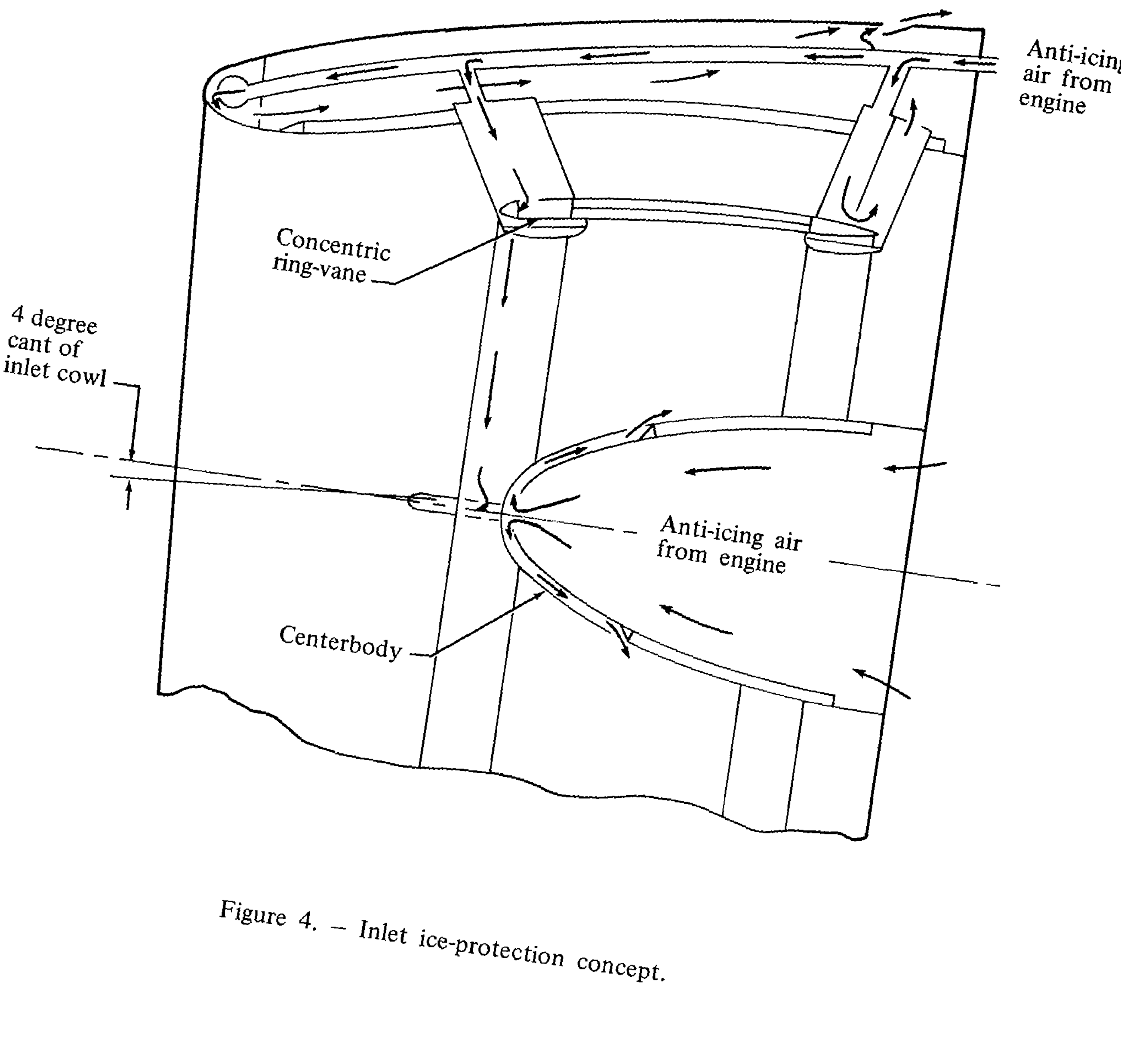
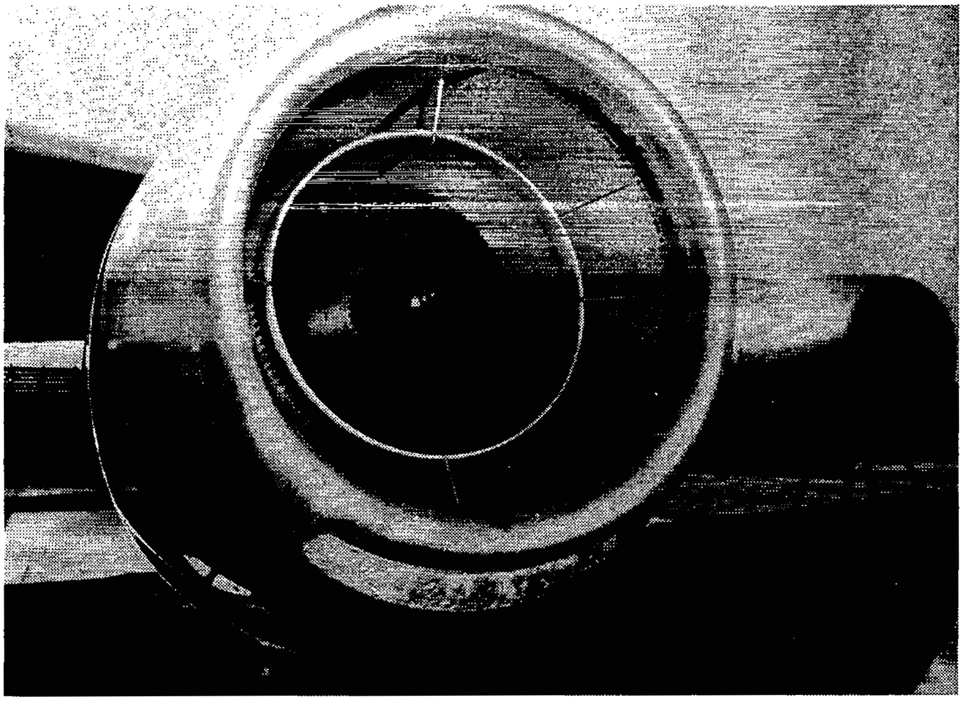
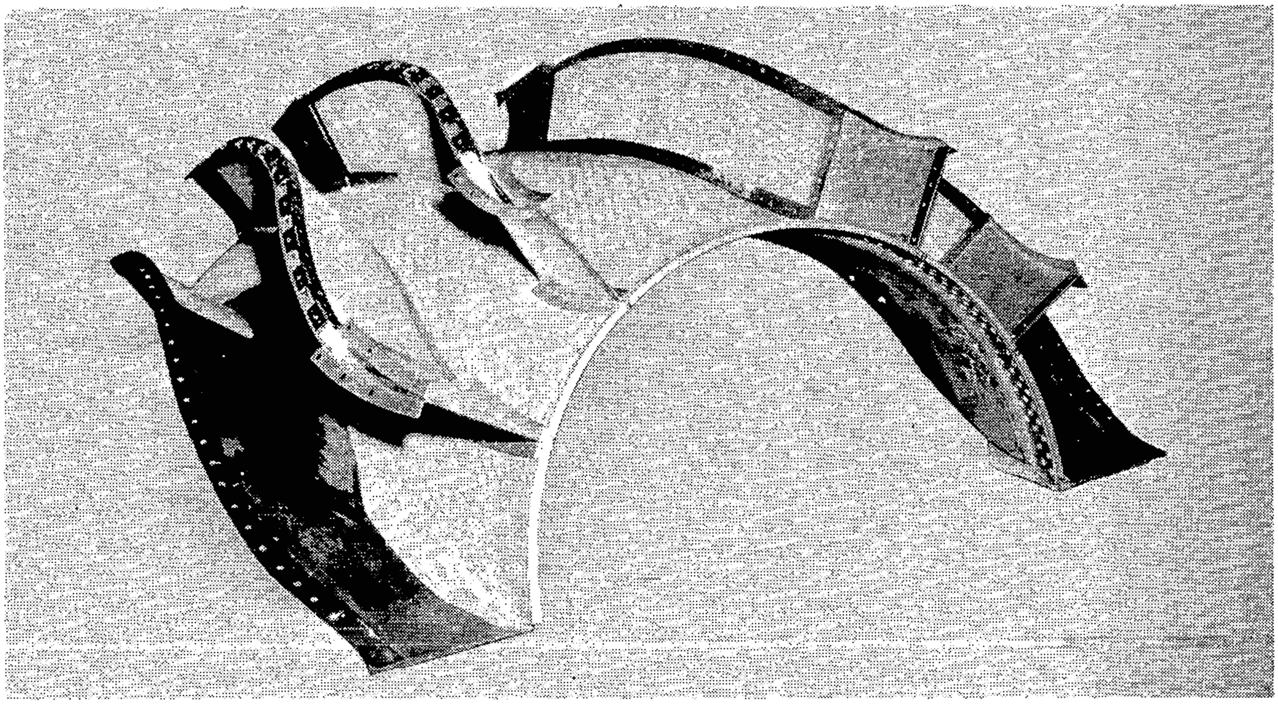


Figure 4. – Inlet ice-protection concept.



(a) Inlet duct and concentric ring.



(b) Fan-exhaust inner wall and flow splitters.

Figure 5. – Modified flight-test nacelle components.

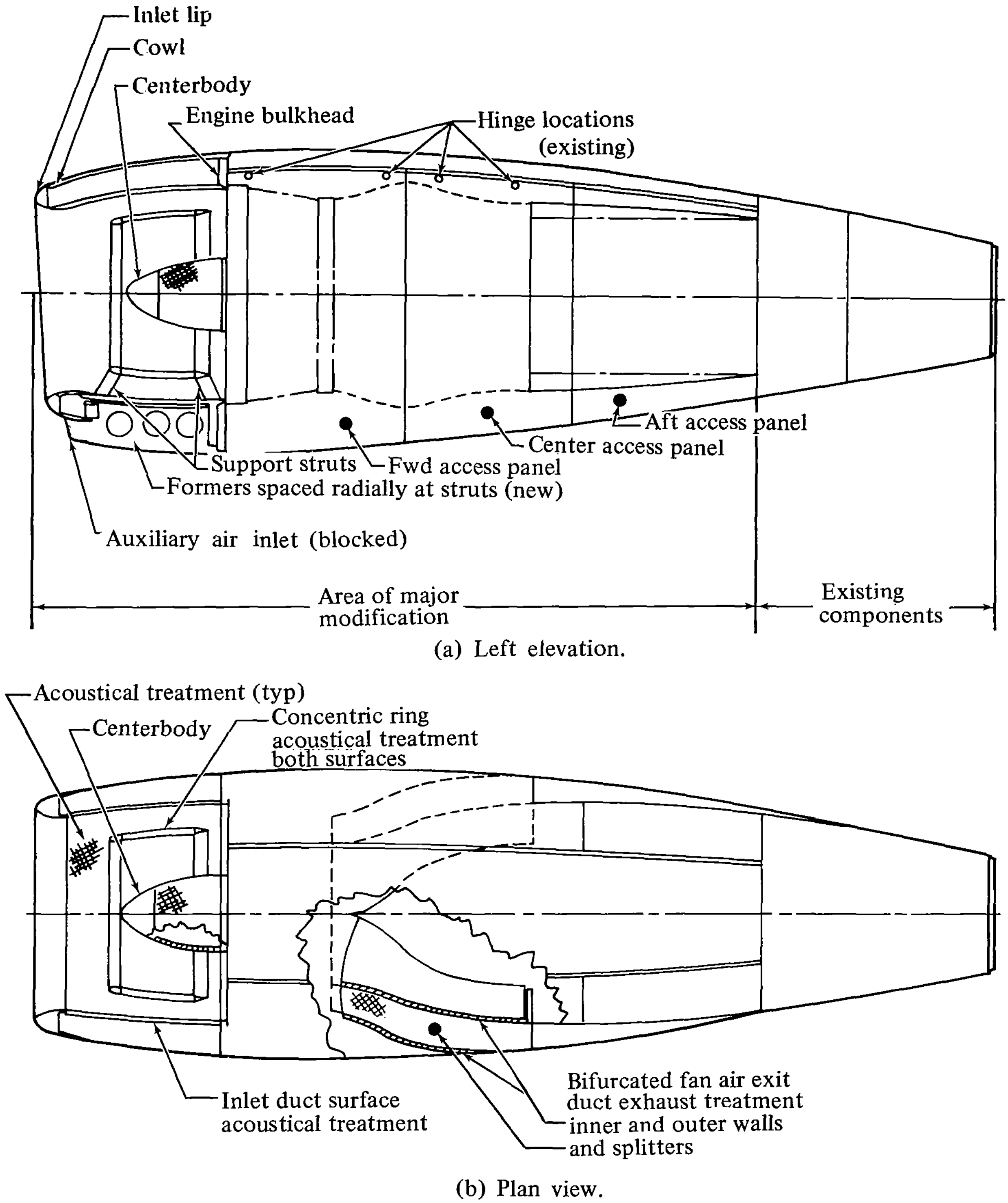
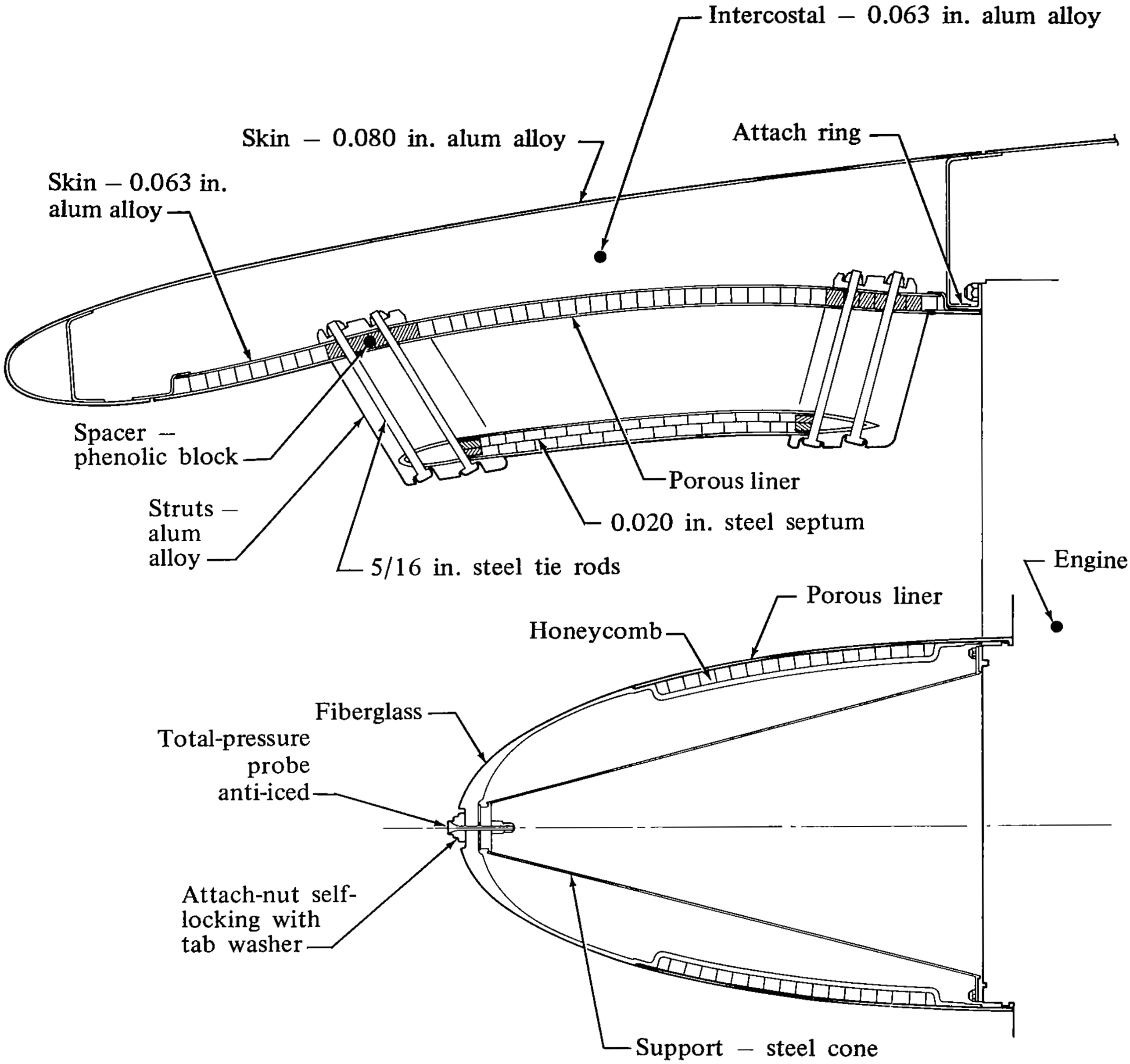
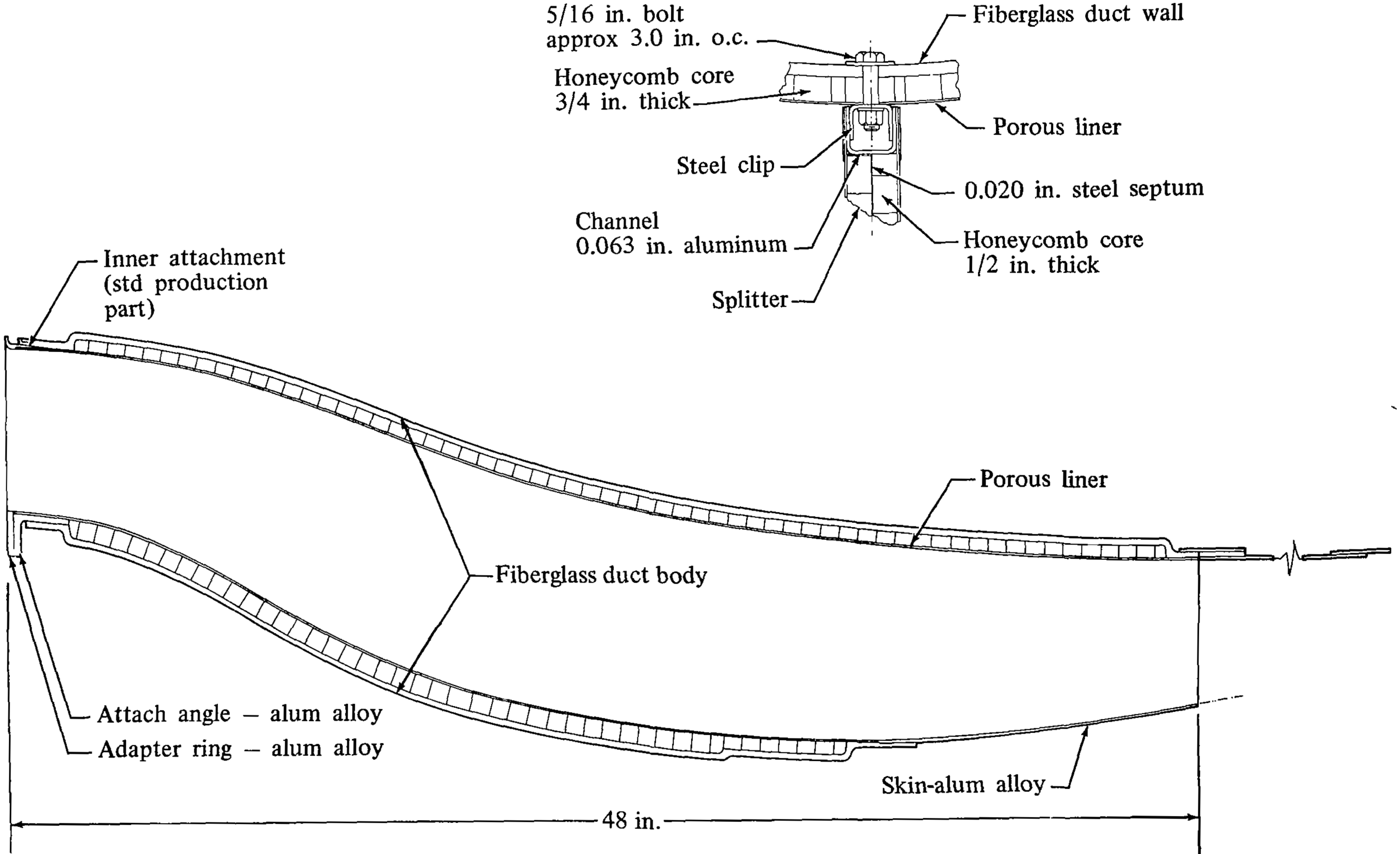


Figure 6. – Test configurations of the modified nacelle.



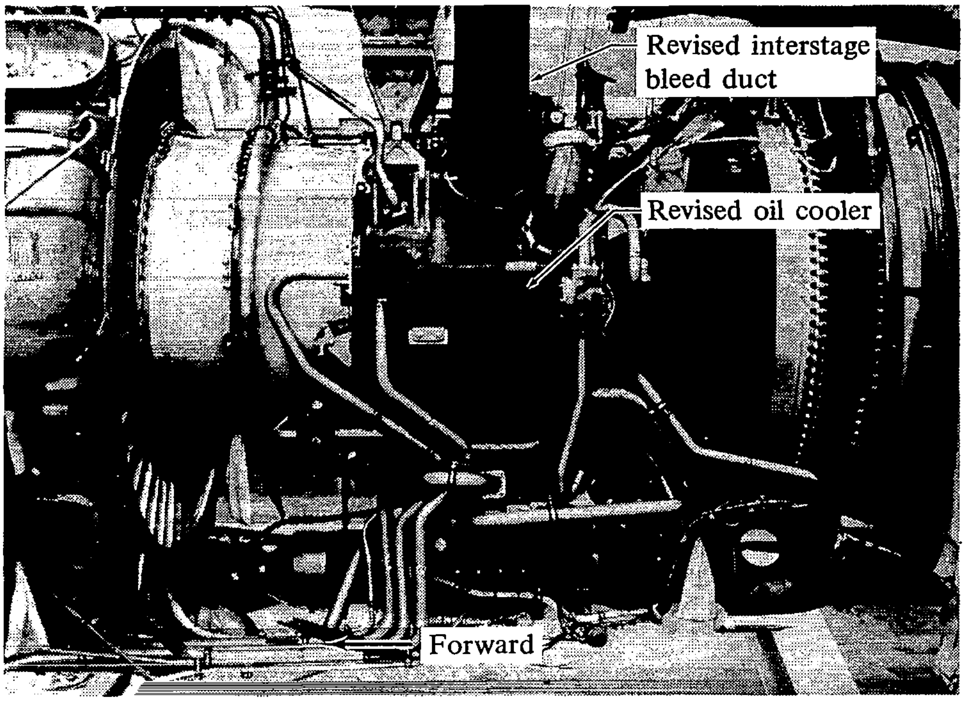
(c) Inlet duct, concentric ring, and centerbody.

Figure 6. – Continued.

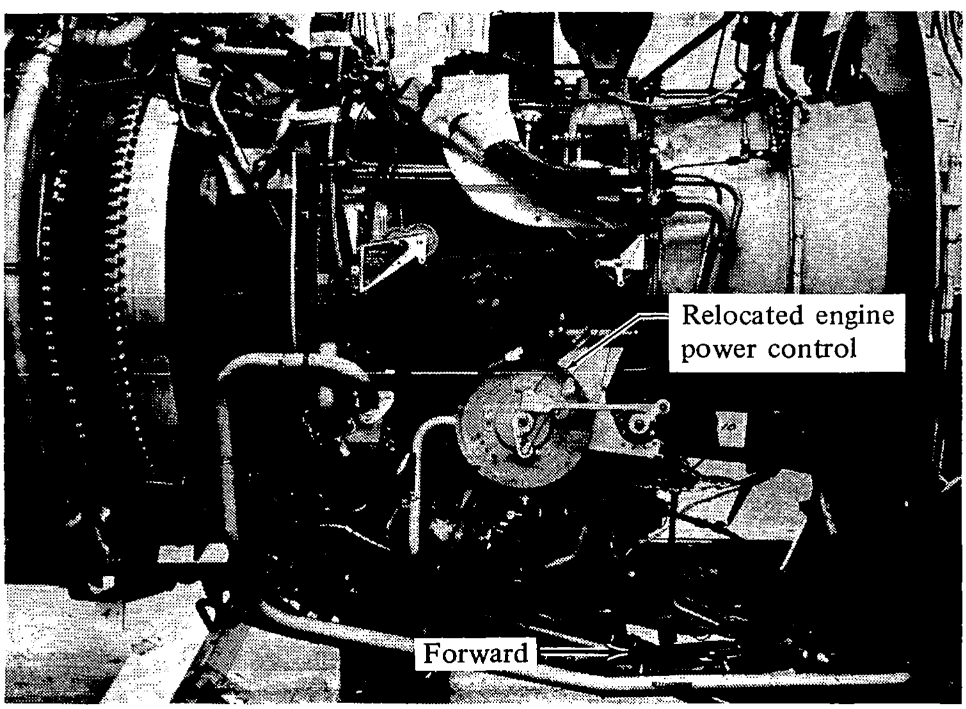


(d) Fan exhaust duct.

Figure 6. – Concluded.

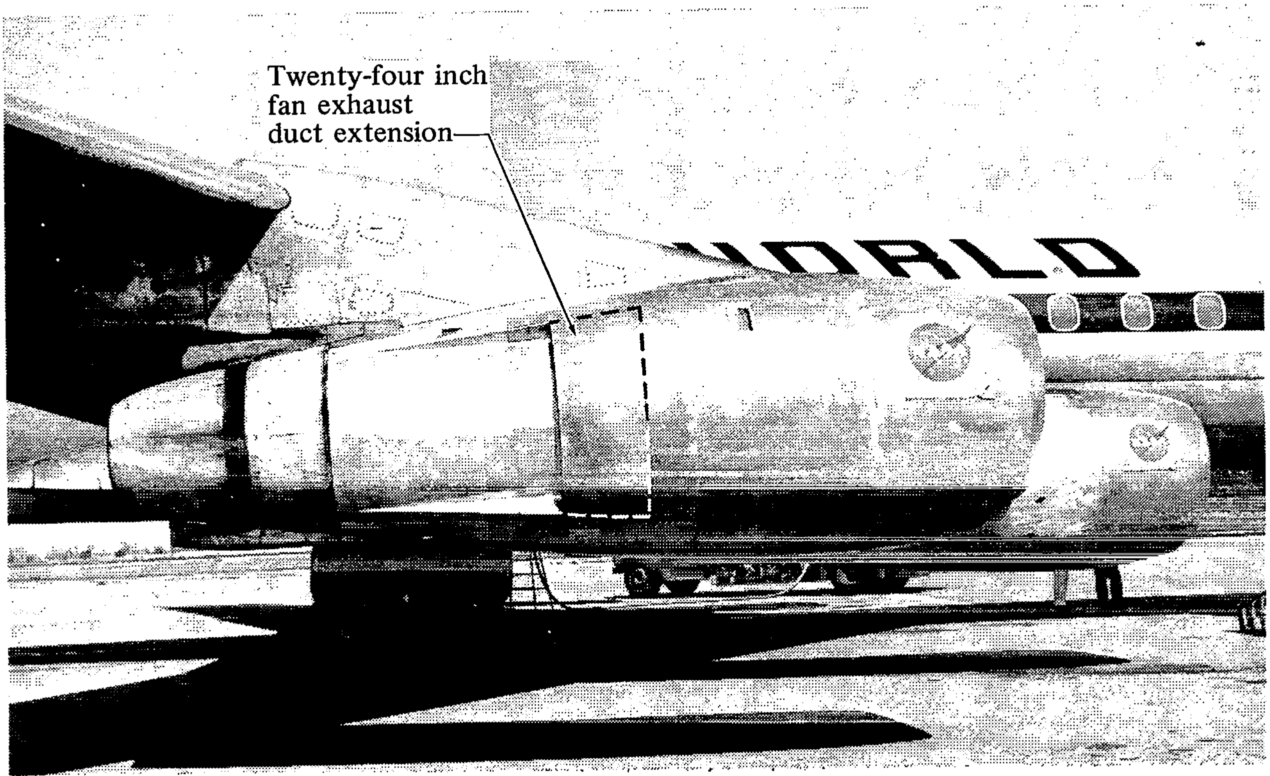


(a) Left side.

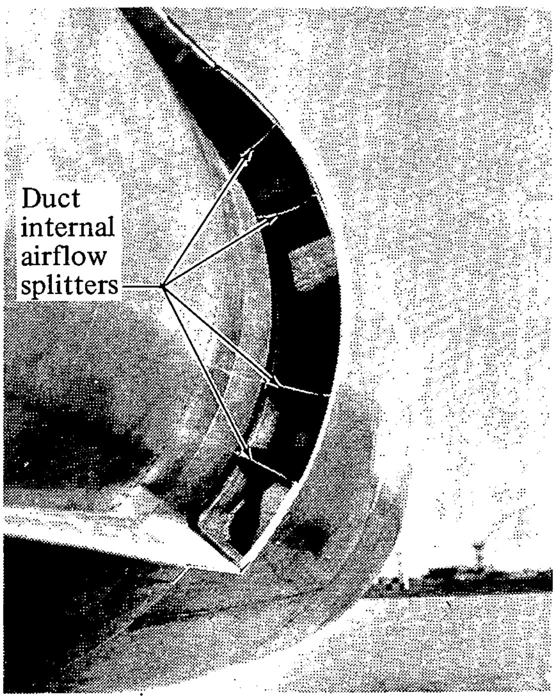


(b) Right side.

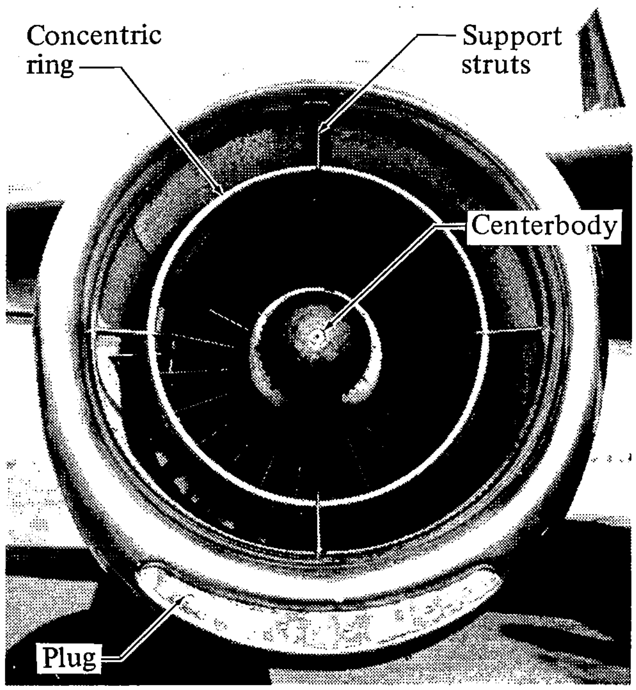
Figure 7. – Mockup engine installation with fan exhaust ducts removed.



(a) Side view.



(b) Aft view of fan-exhaust duct.



(c) Front view of inlet.

Figure 8. – Test nacelle installed on the DC-8-55 airplane.

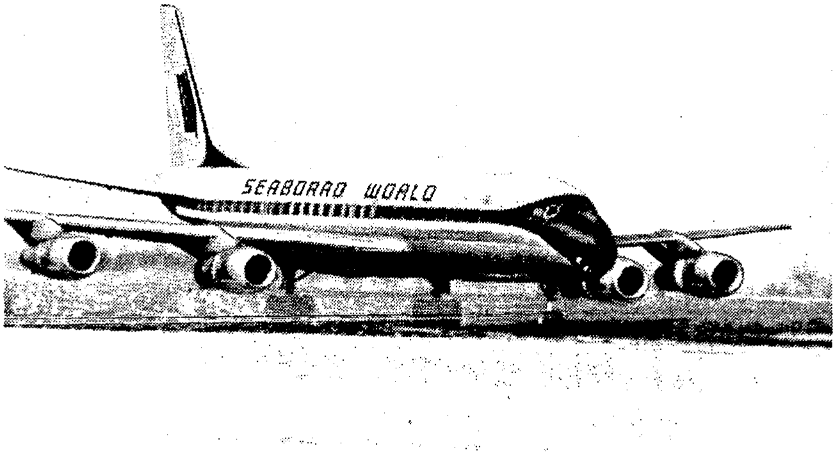
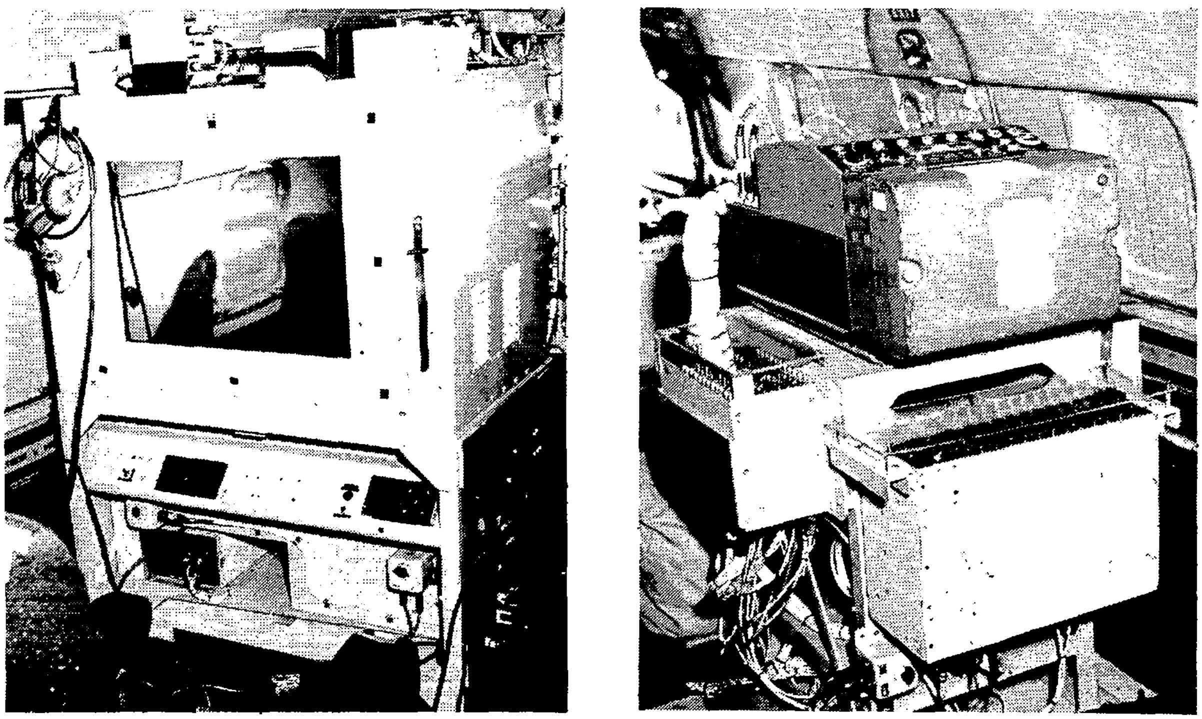
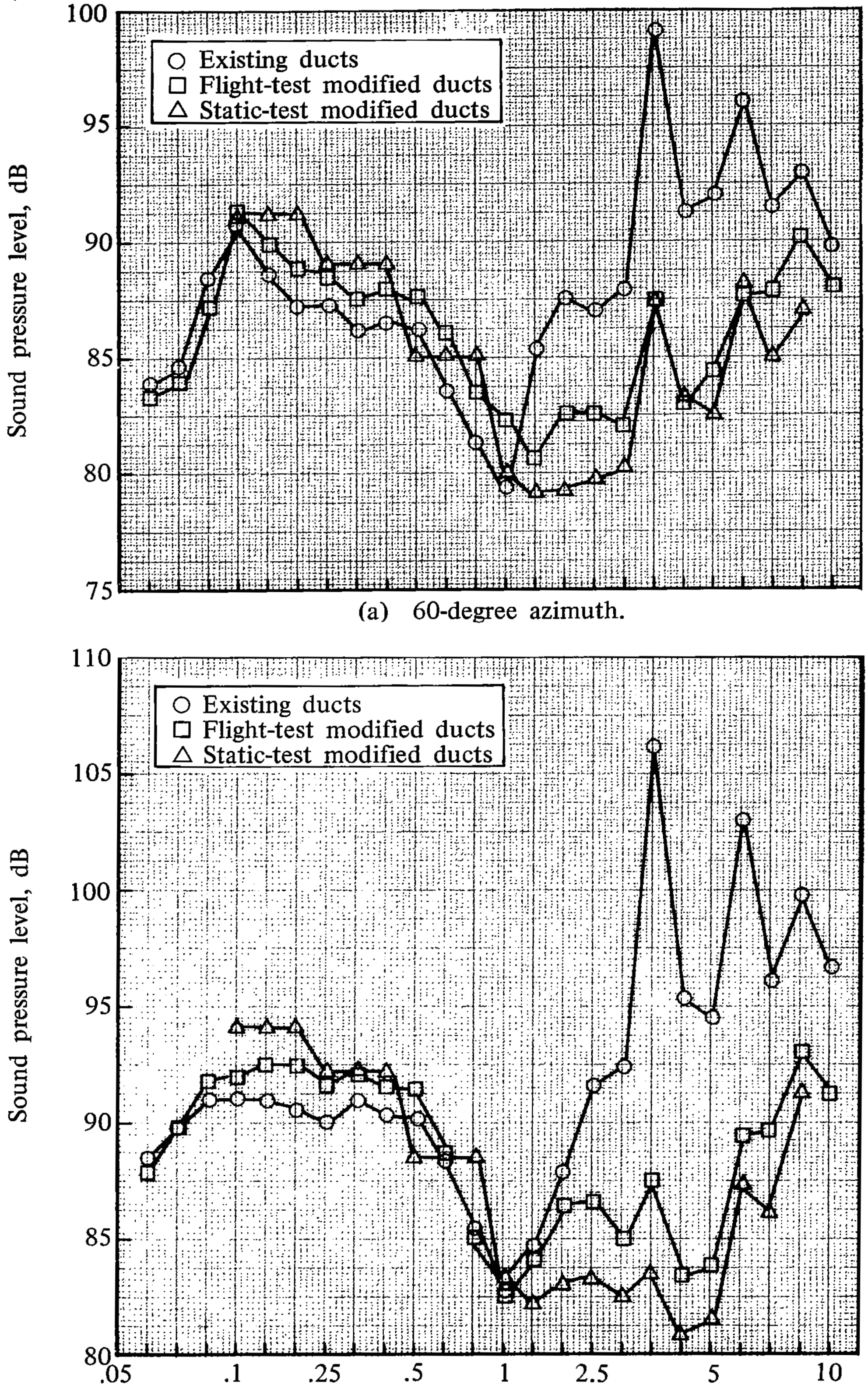


Figure 9. – DC-8-55 test airplane.



(a) Photorecorder. (b) Oscillograph.

Figure 10. – Airborne flight test recorders.



(b) 110-degree azimuth.

Figure 11. – SPL spectra at 150 feet for 4600-rpm referred N_1 rotor speed.

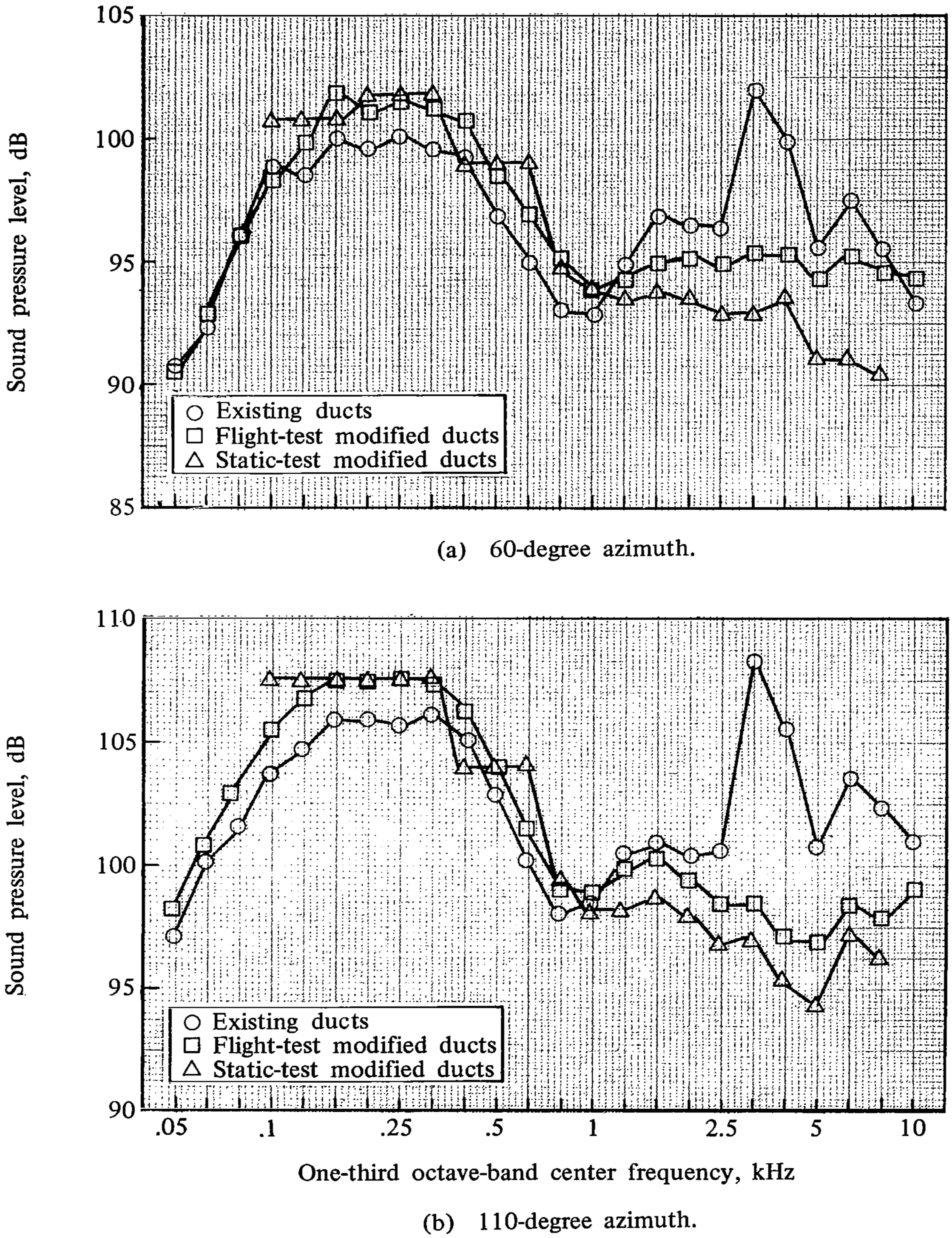
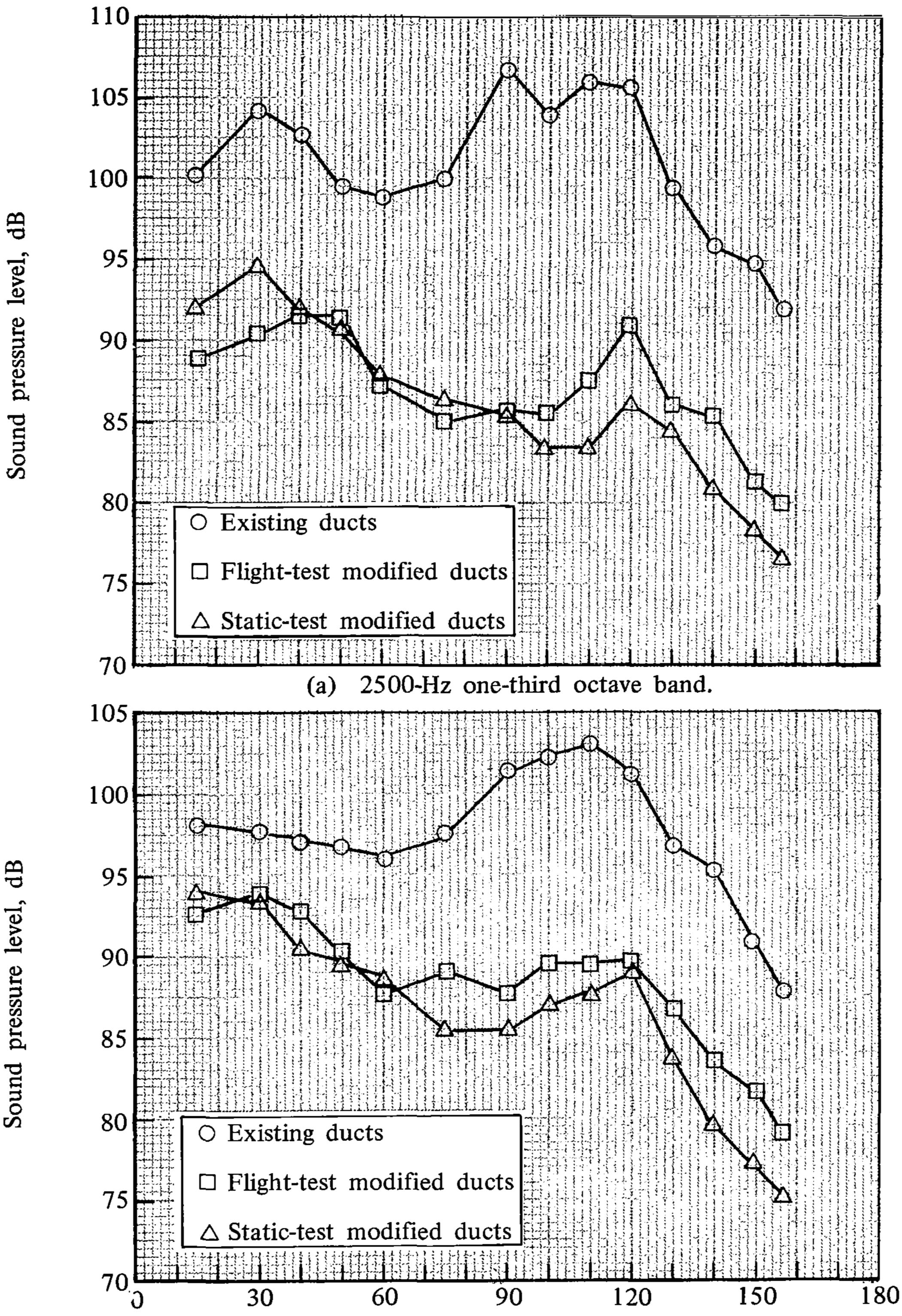


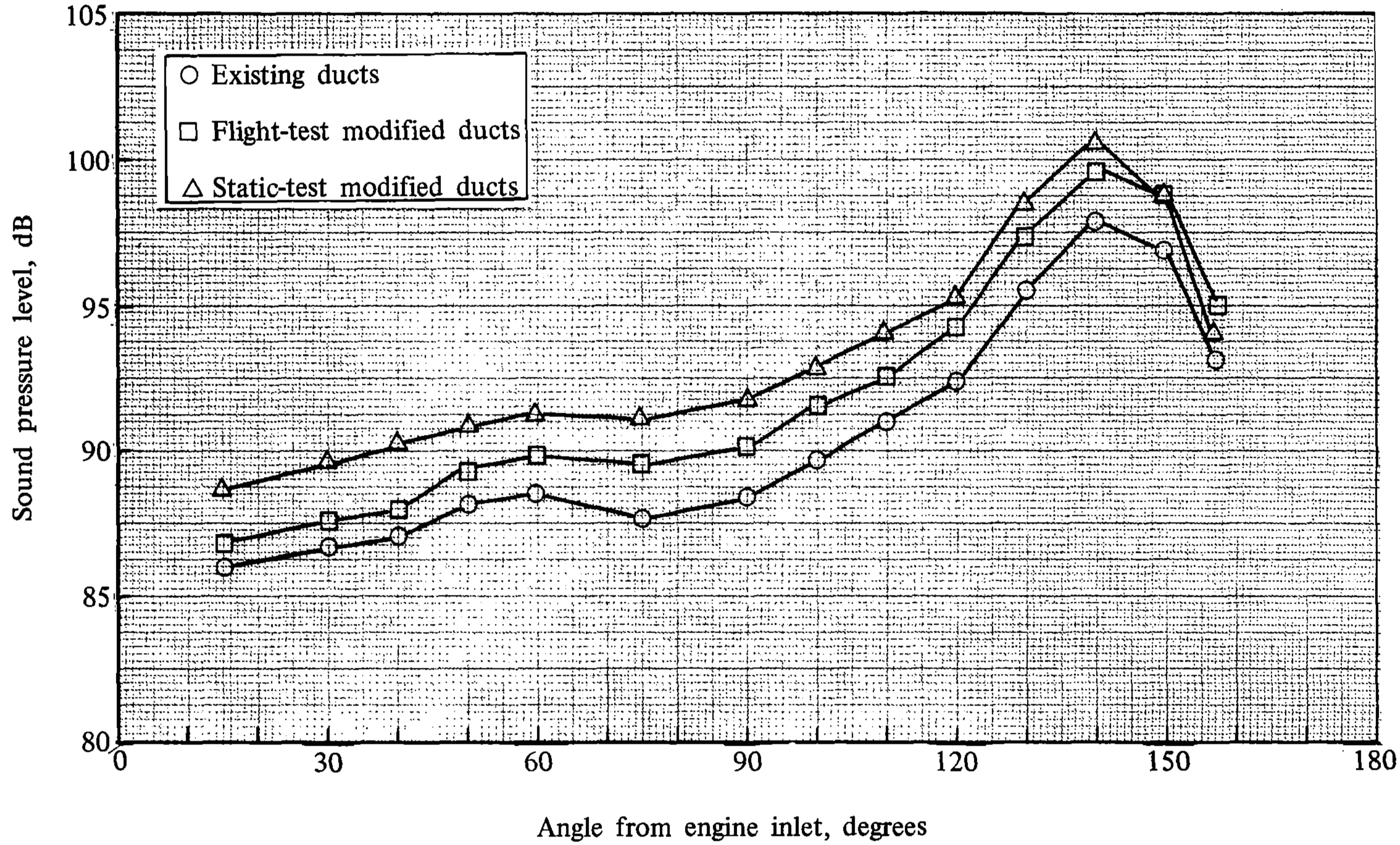
Figure 12. – SPL spectra at 150 feet for 6300-rpm referred N_1 rotor speed.



(a) 2500-Hz one-third octave band.

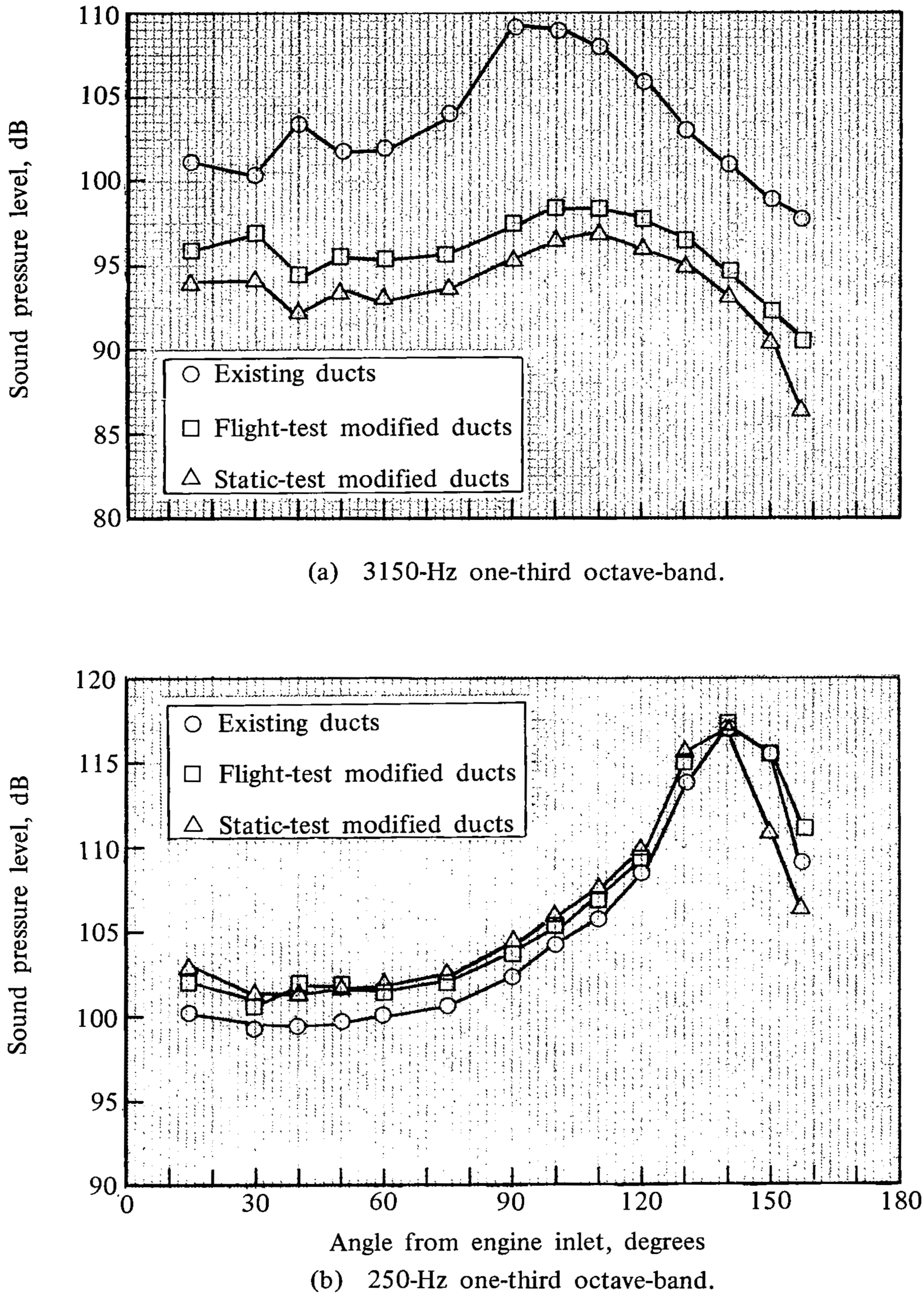
(b) 5000-Hz one-third octave band.

Figure 13. – Directivity at 150 feet for 4600-rpm referred N_1 rotor speed.



(c) 125-Hz one-third octave band.

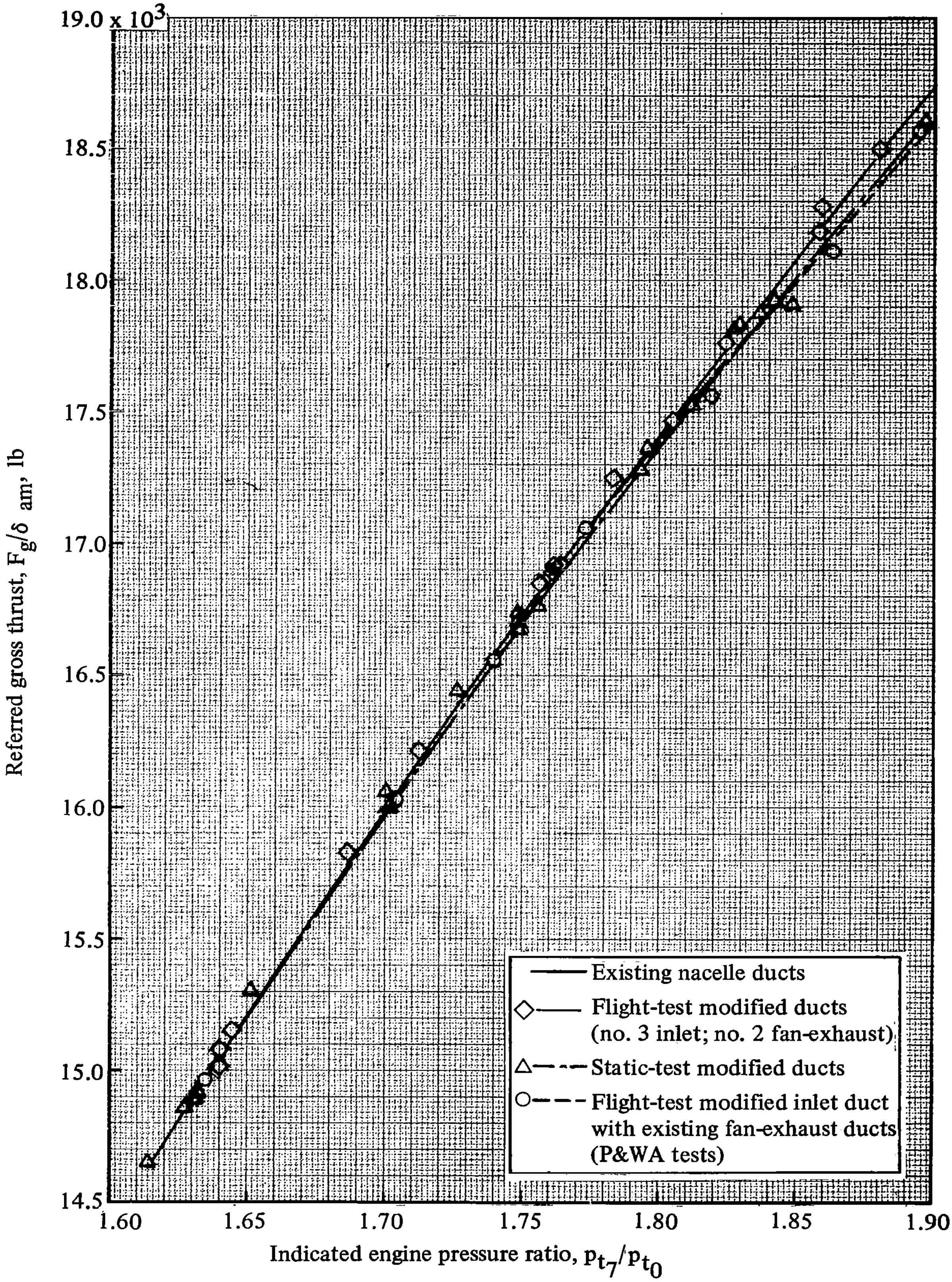
Figure 13. – Concluded.



(a) 3150-Hz one-third octave-band.

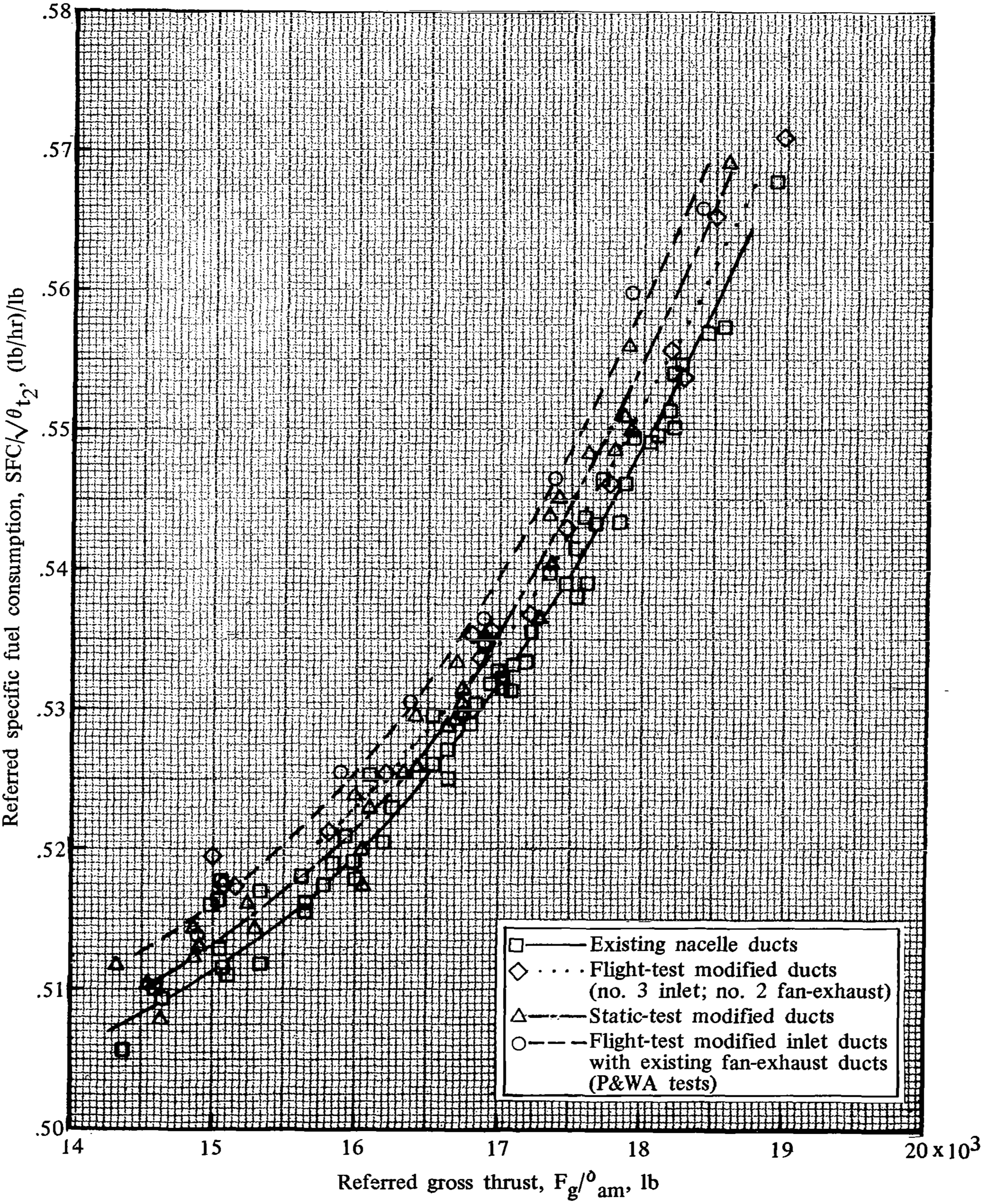
(b) 250-Hz one-third octave-band.

Figure 14. – Directivity at 150 feet for 6300-rpm referred N_1 rotor speed.



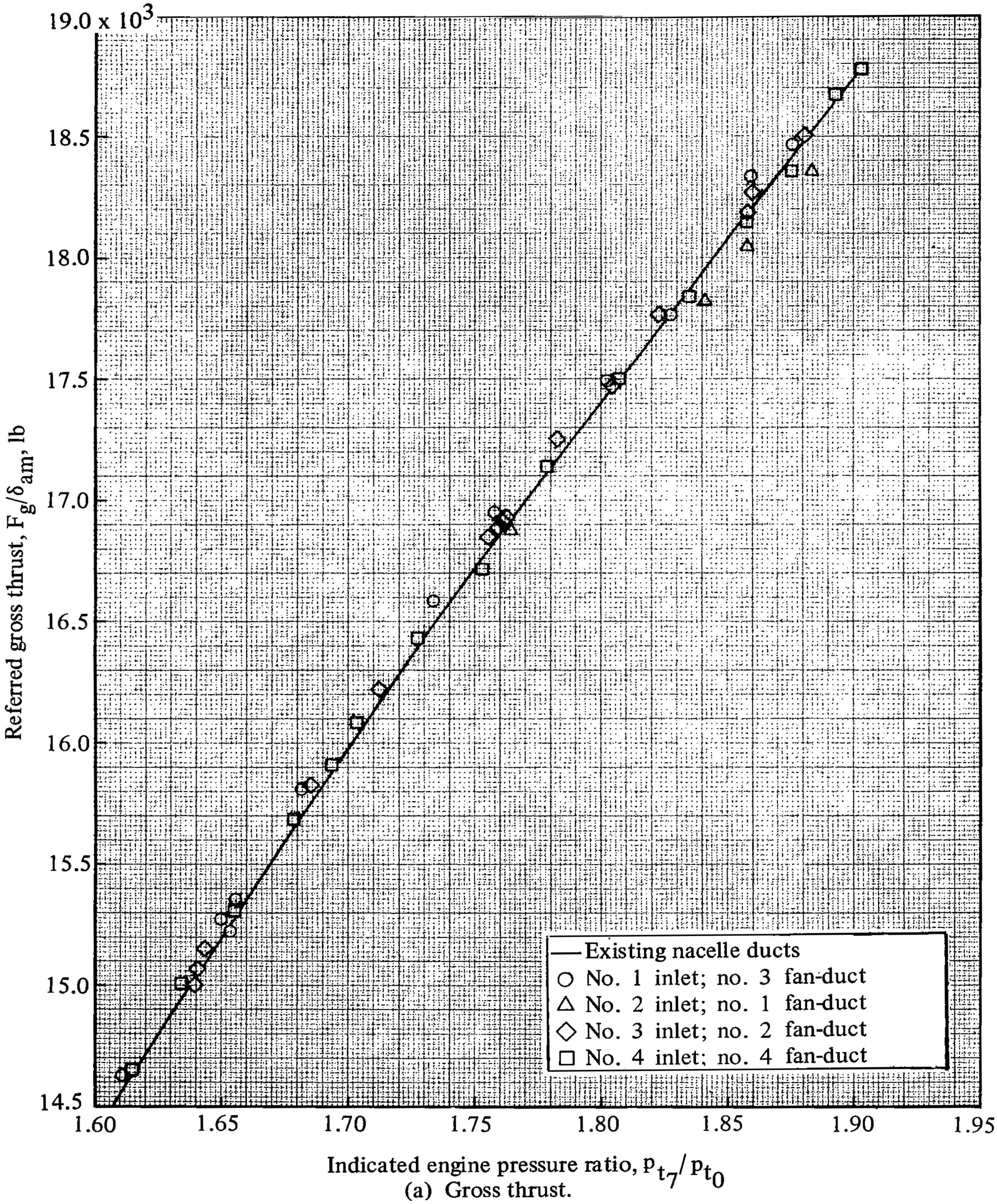
(a) Gross thrust.

Figure 15. – Test-stand engine performance with various modified and existing nacelle ducts.



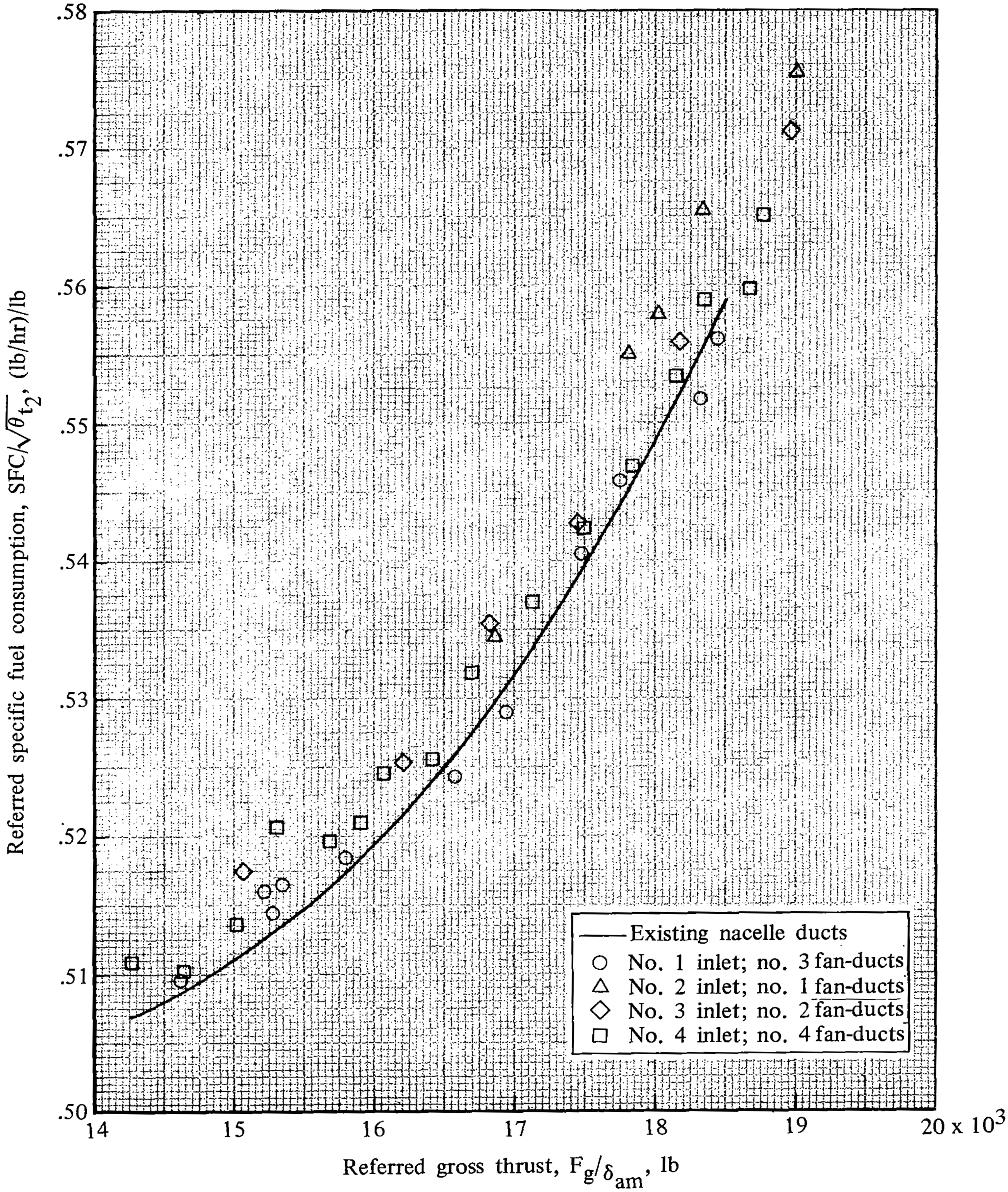
(b) Fuel consumption.

Figure 15. – Concluded.



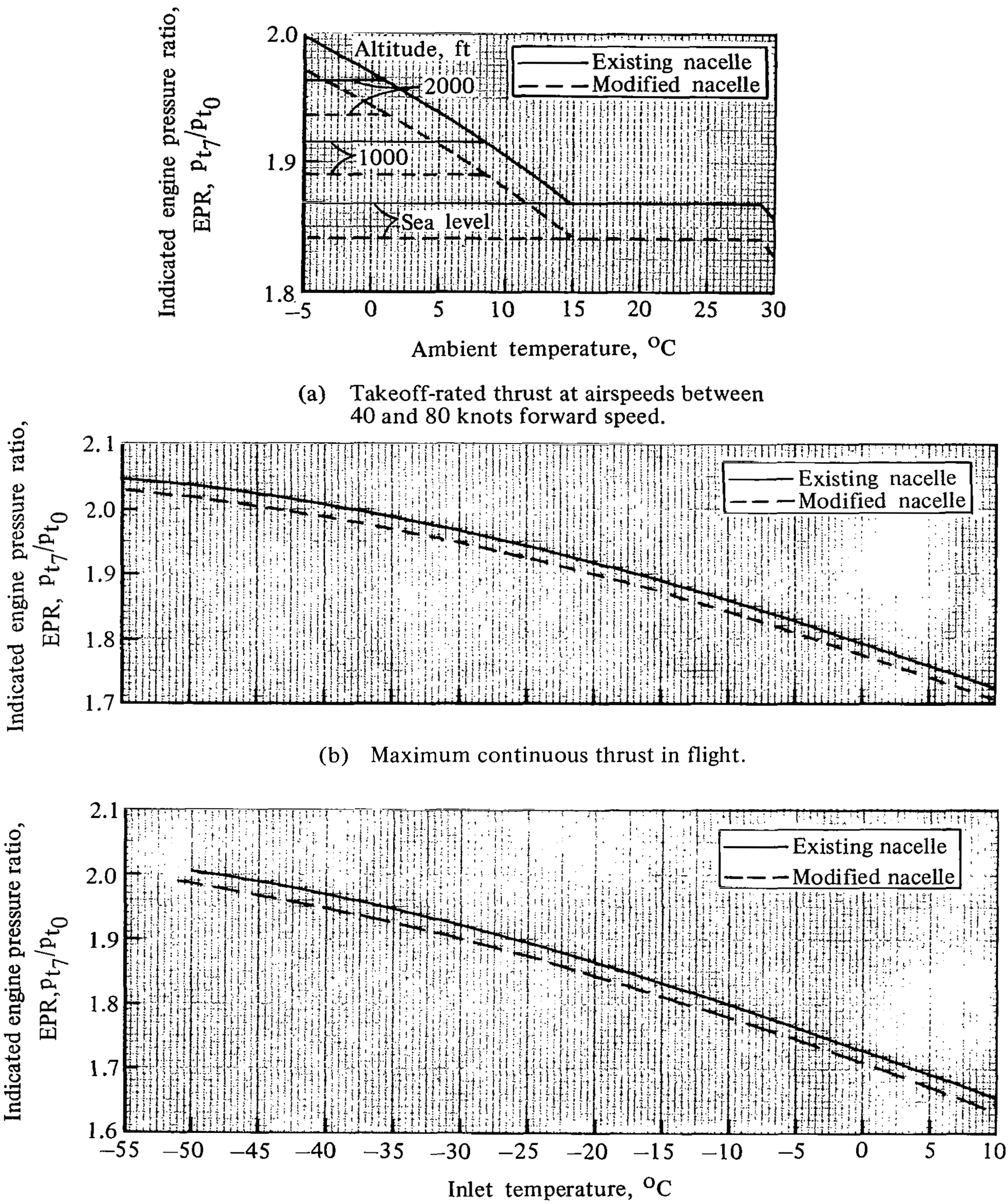
(a) Gross thrust.

Figure 16. – Test stand performance with the four ducting sets for the flight-test modified nacelle.



(b) Fuel consumption.

Figure 16. – Concluded.



(a) Takeoff-rated thrust at airspeeds between 40 and 80 knots forward speed.

(b) Maximum continuous thrust in flight.

(c) Maximum cruise thrust.

Figure 17. – Rated EPR settings for the JT3D-3B engine.

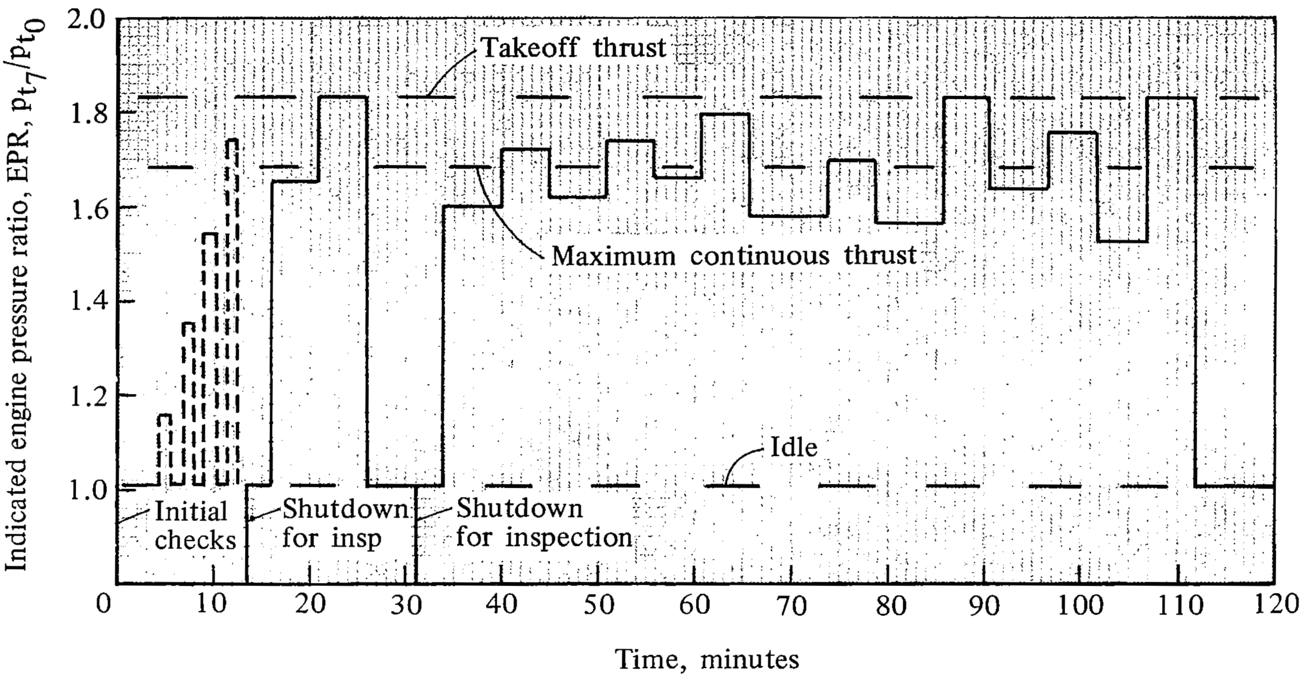


Figure 18. – Typical engine operating sequence for structural testing of modified nacelle.

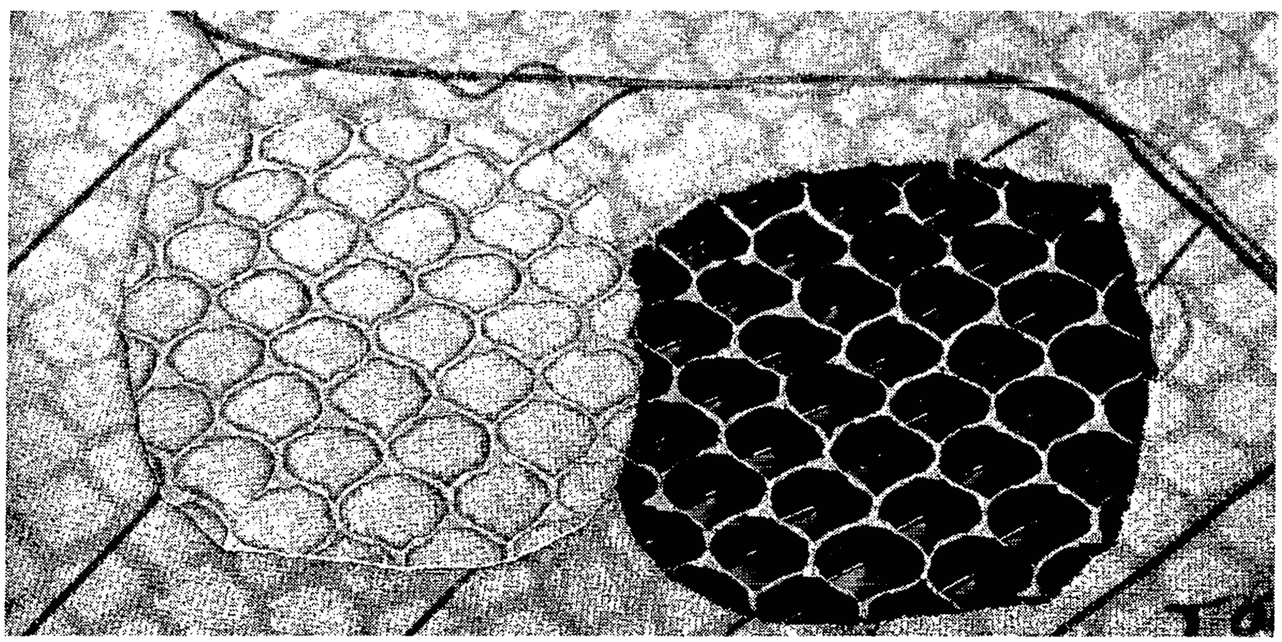
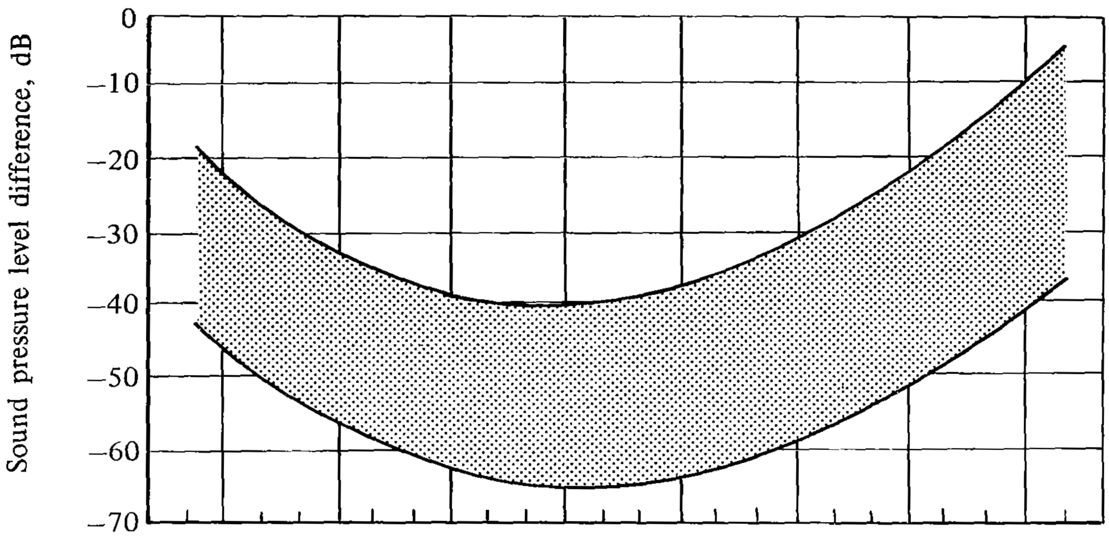
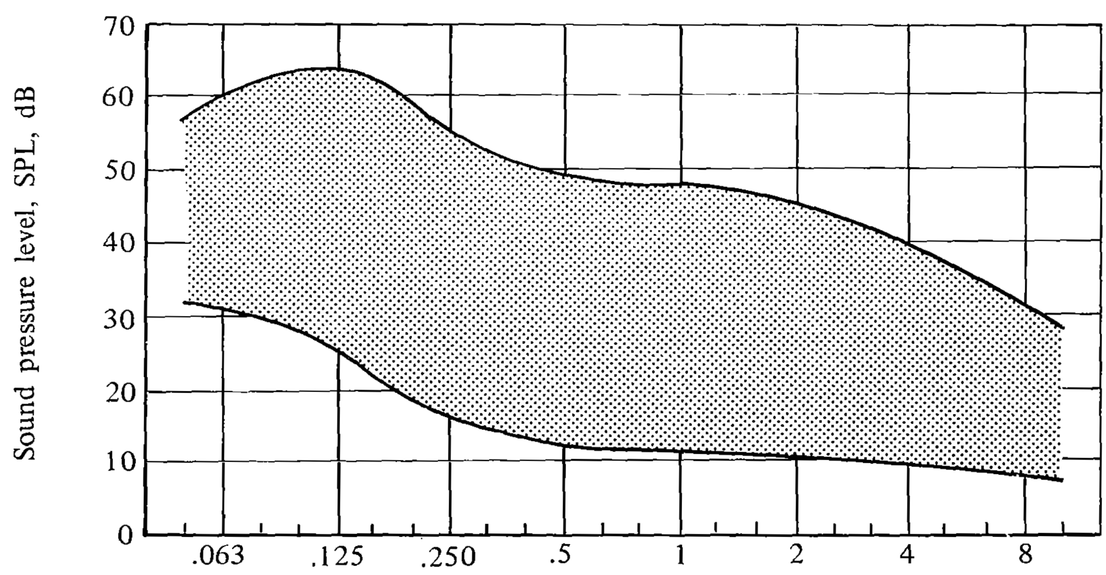


Figure 19. – Bonding failure in the no. 1 flight inlet duct.



(a) Range of differences between ambient and aircraft SPLs (ambient minus peak airplane SPLs).



(b) Range of ambient sound pressure levels for all sounding recording stations.

Figure 20. – Test site ambient noise levels.

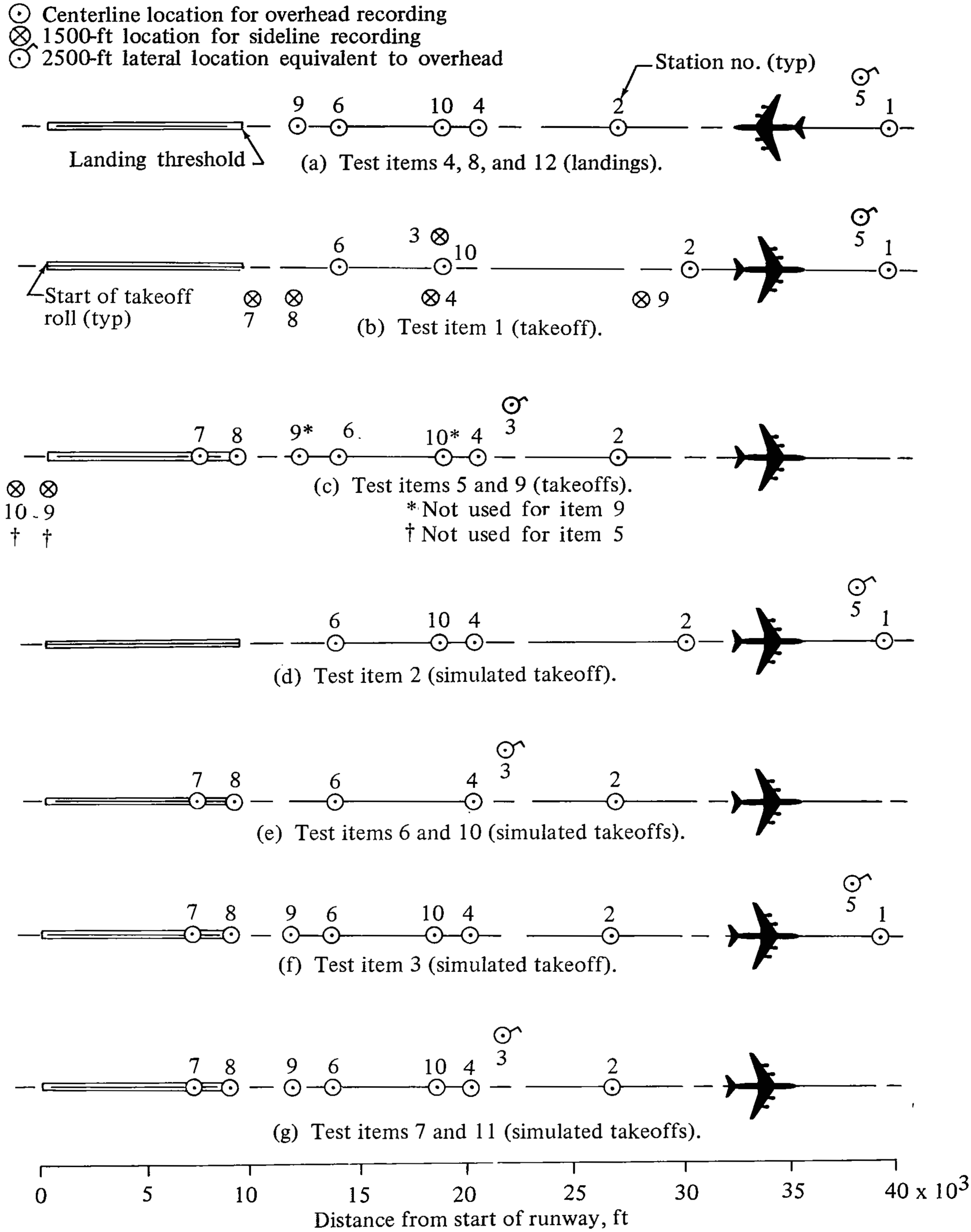
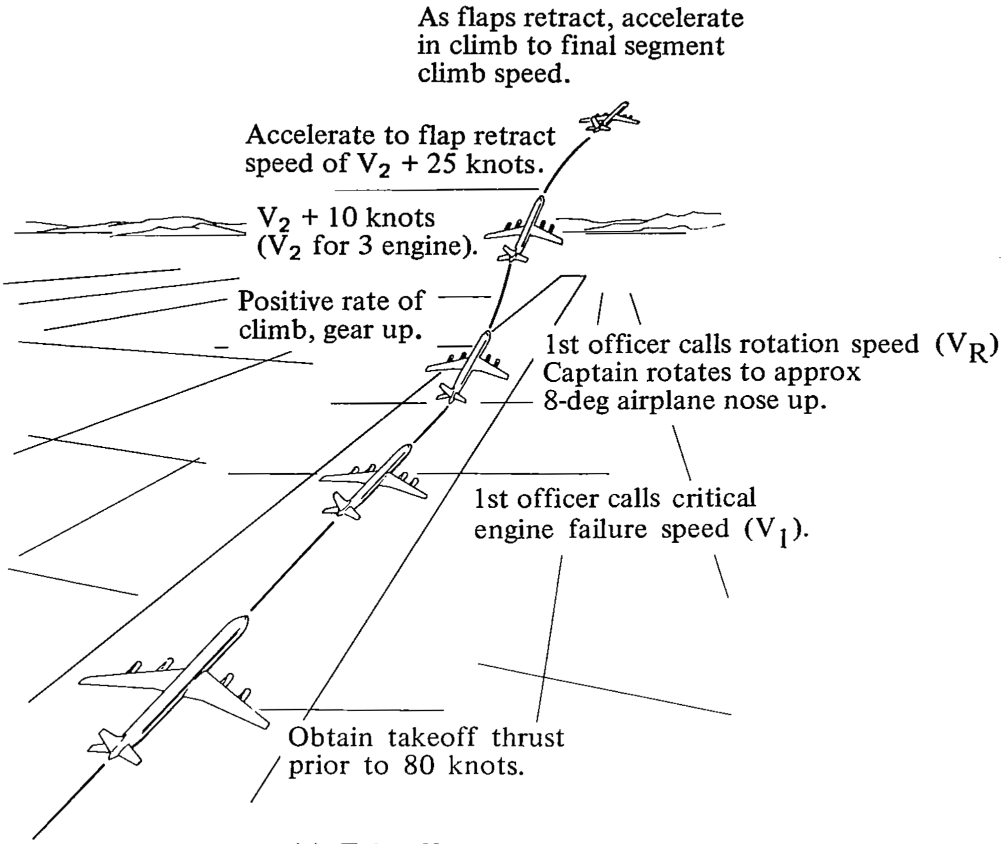
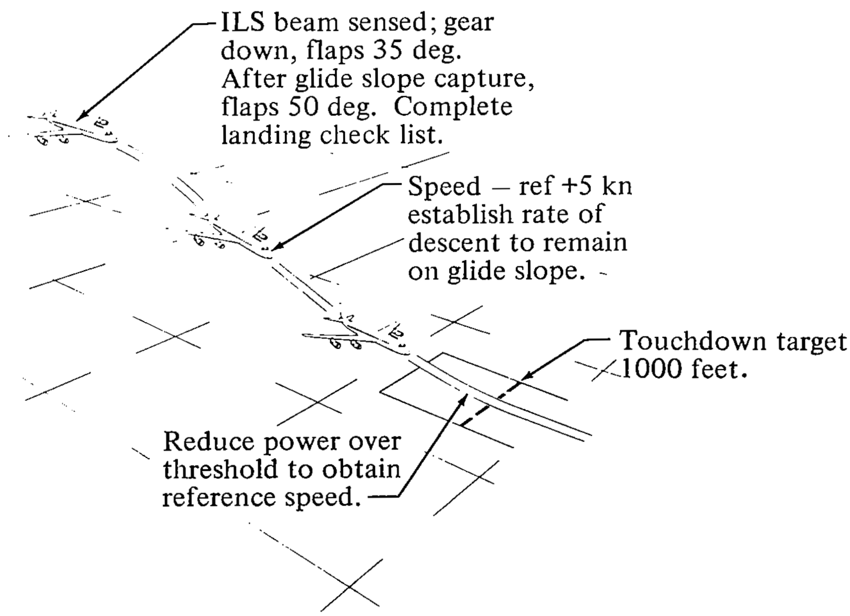


Figure 21.– Sound station locations.



(a) Takeoff.



(b) Landing.

Figure 22. – Douglas-recommended flight procedures.

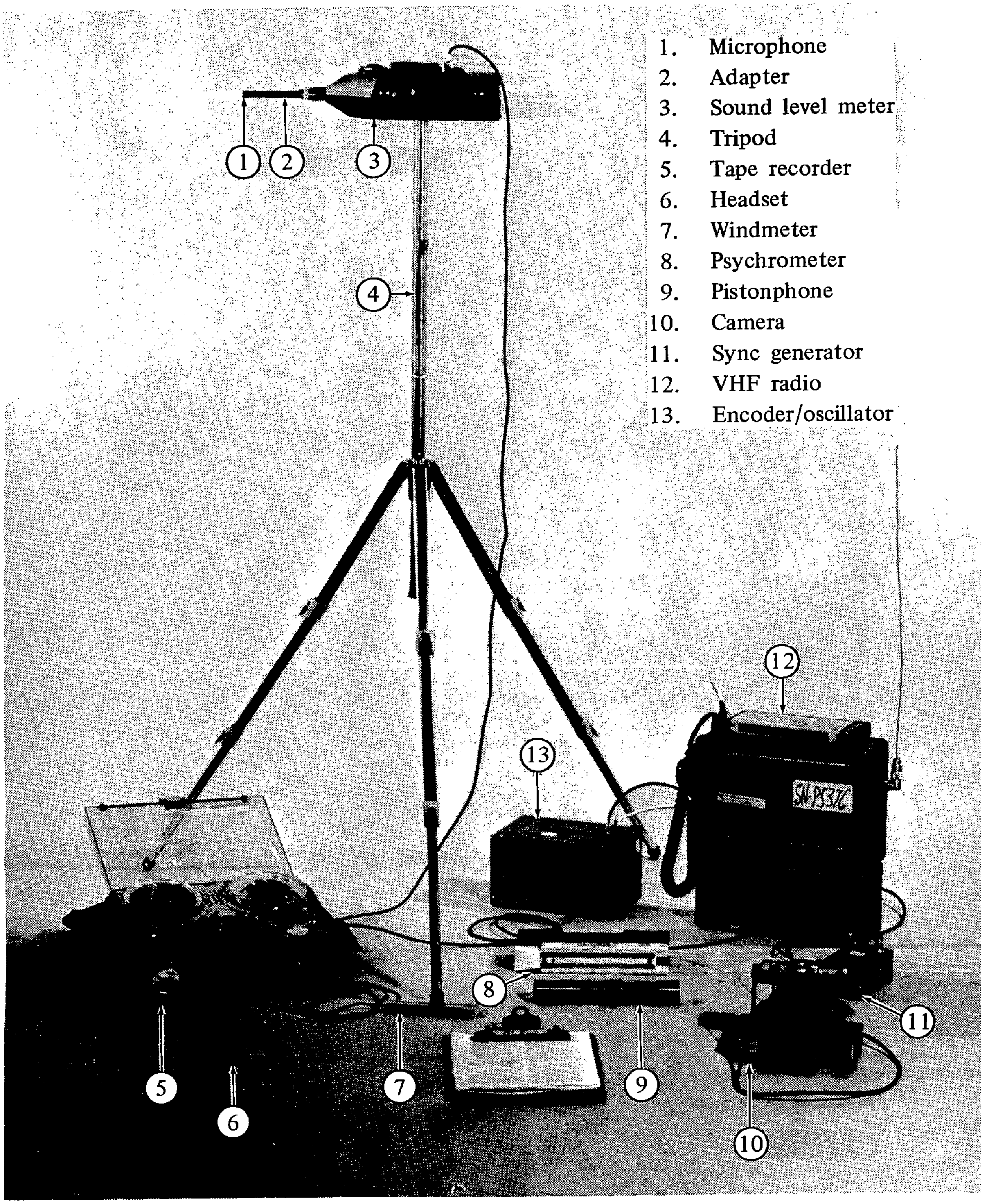


Figure 23. – Sound station equipment.

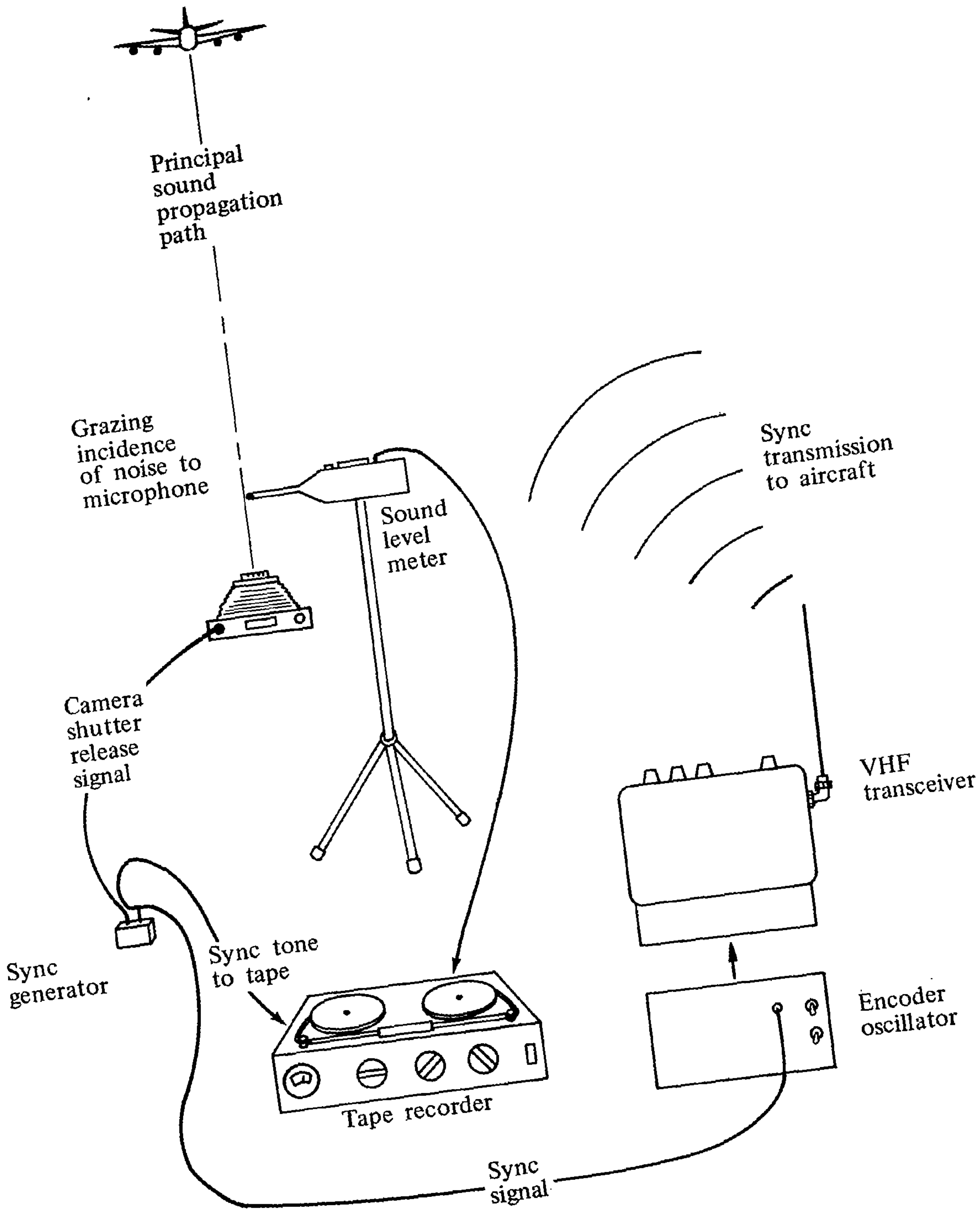


Figure 24. – Sound station system.

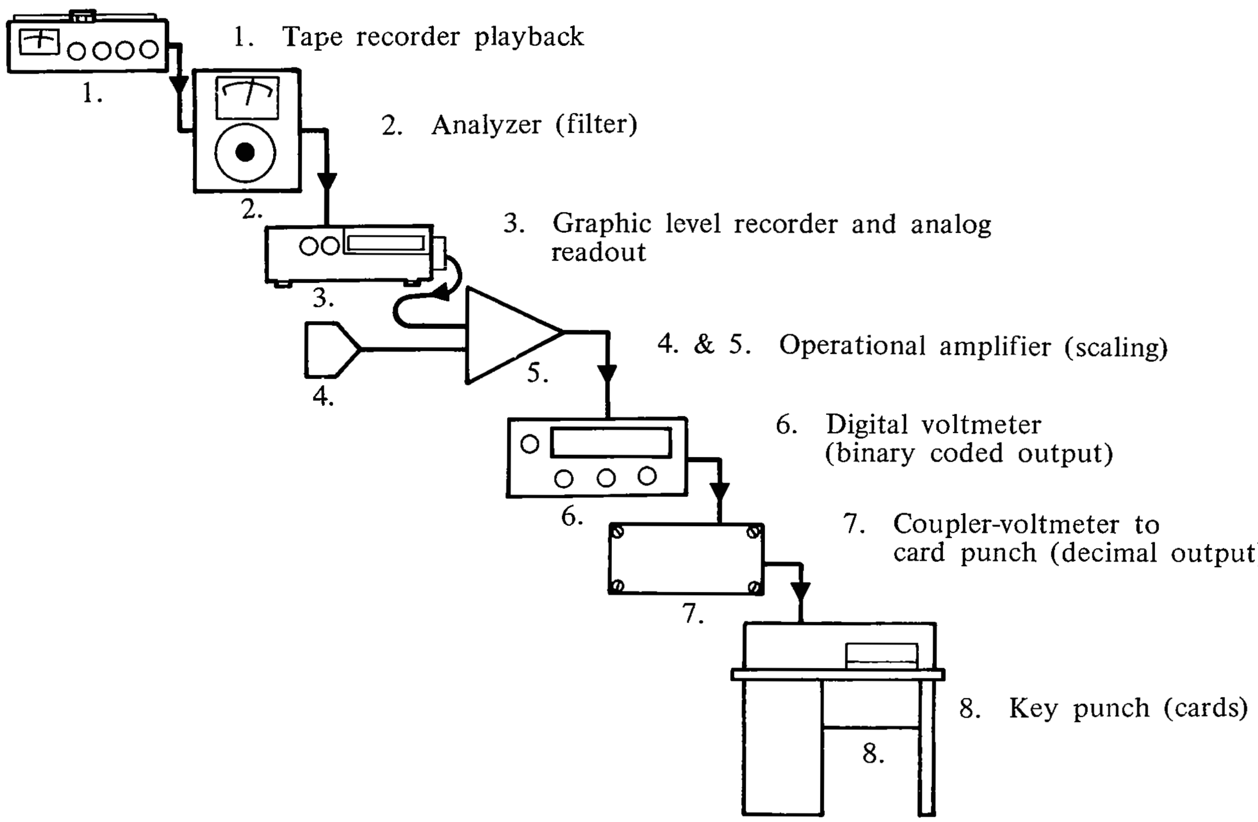
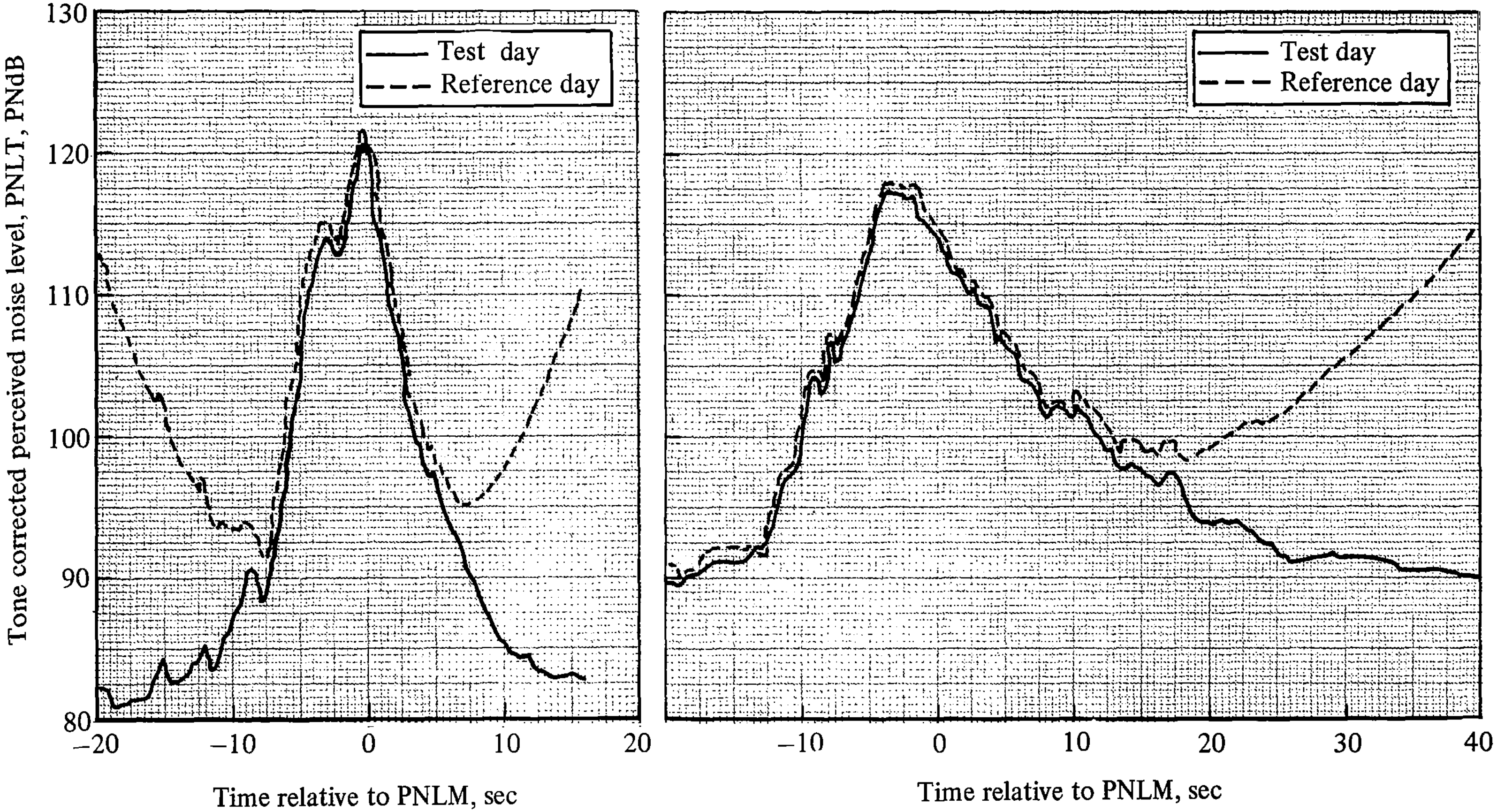


Figure 25. – Flyover noise data reduction system.



(a) Landing.

(b) Takeoff.

Figure 26.–Comparison of tone corrected perceived noise level with test-day and reference-day atmospheric conditions. Atmospheric absorption corrections made to reference conditions of 59°F and 70 percent relative humidity using SAE ARP 866.

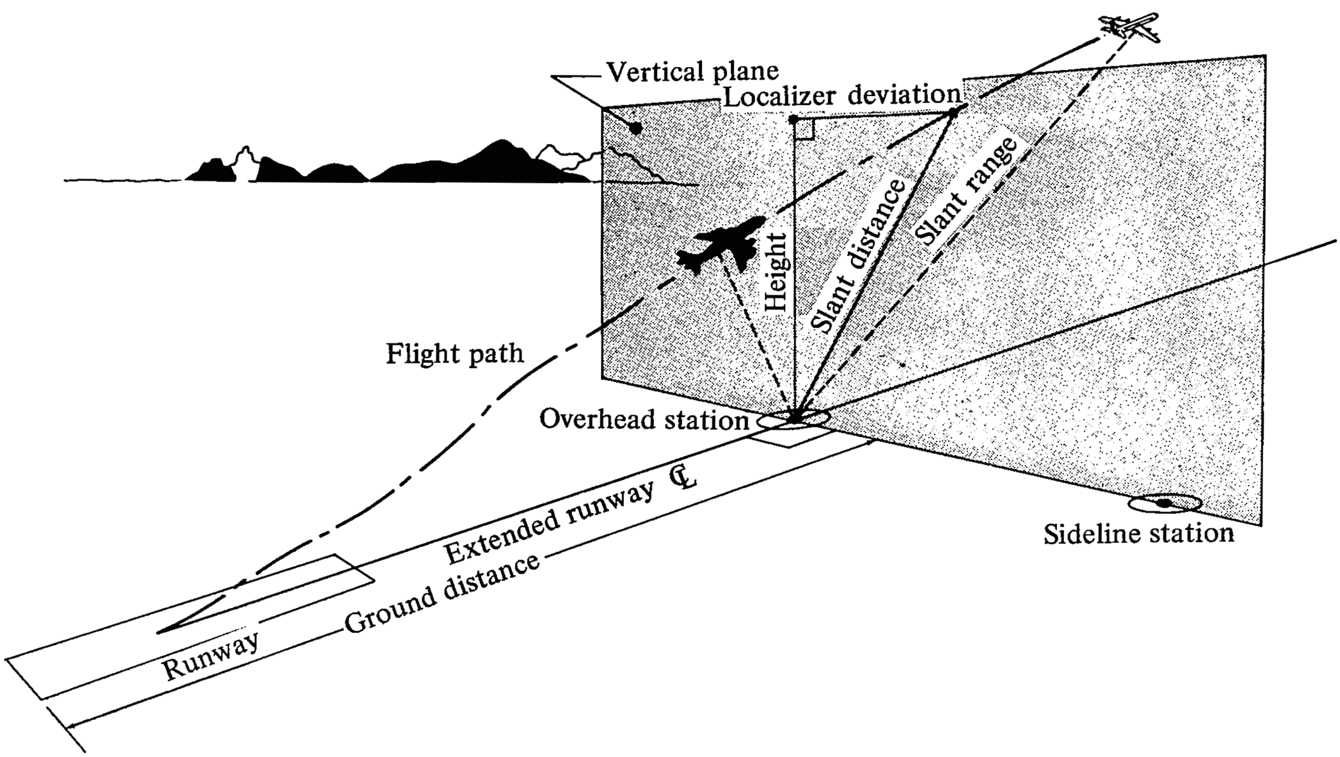
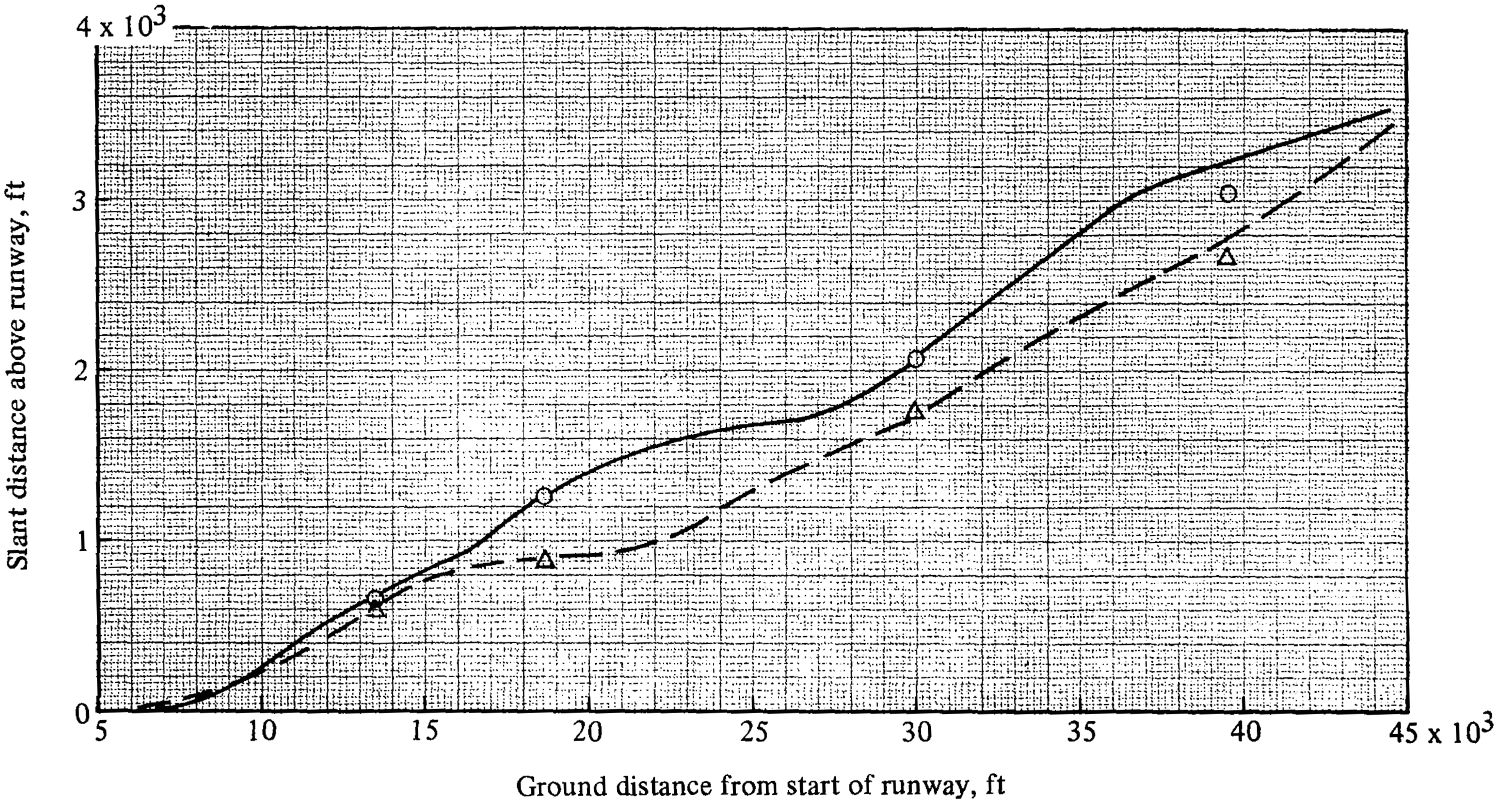


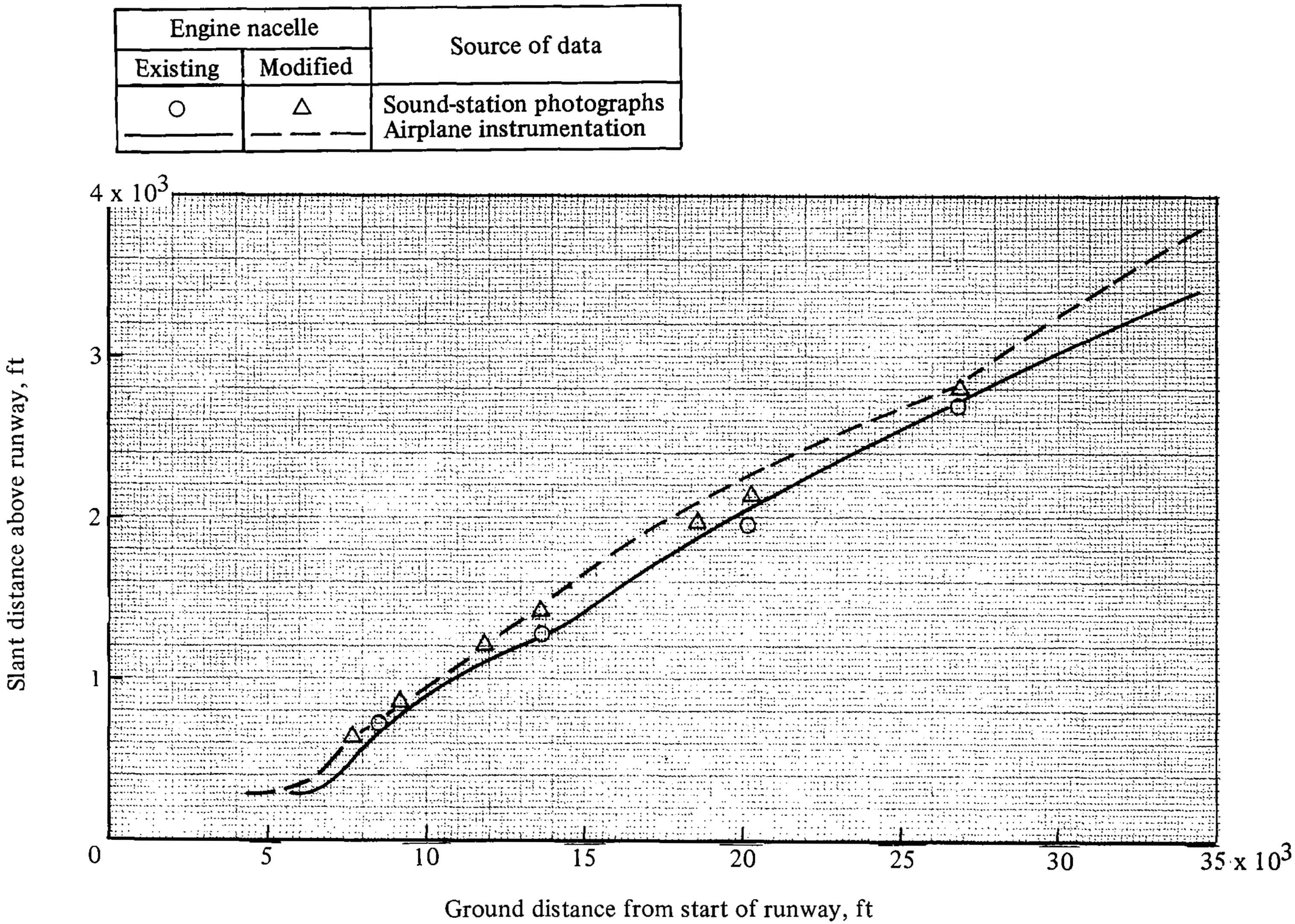
Figure 27. – Space positioning geometry.

Engine nacelle		Source of data
Existing	Modified	
○	△	Sound-station photographs
————	— — —	Airplane instrumentation



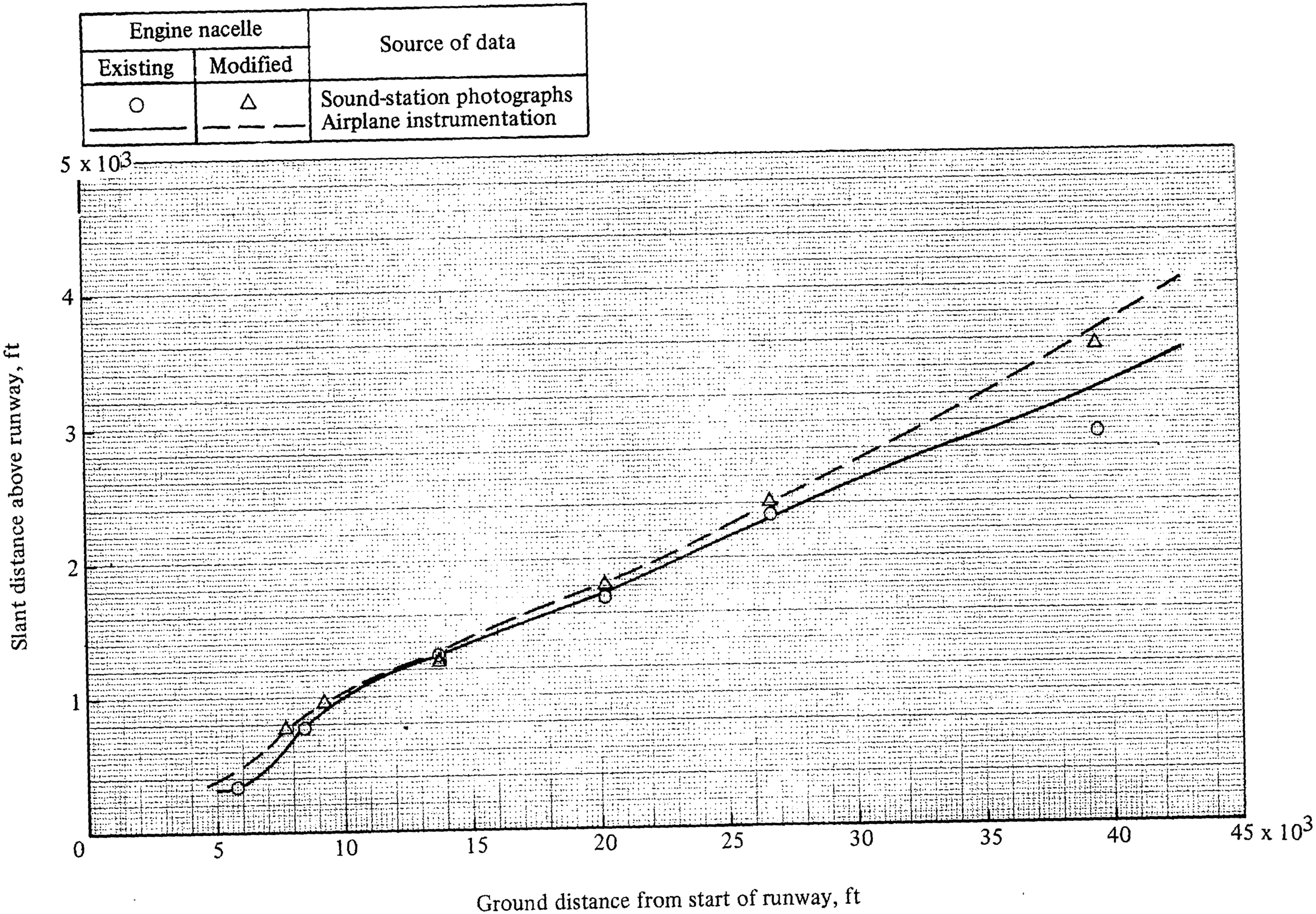
(a) Test item 1, takeoff.

Figure 28. – Representative space positioning results for flyover noise tests.



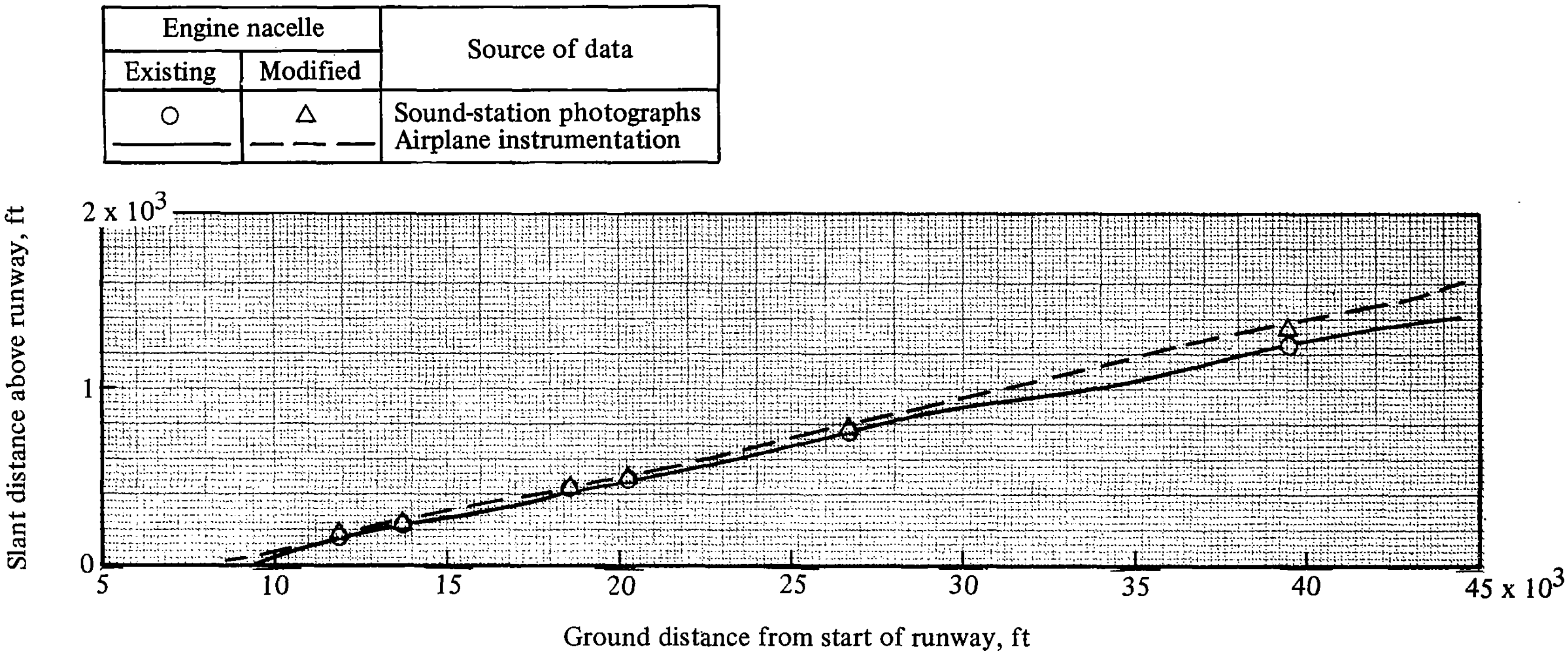
(b) Test item 6, simulated takeoff.

Figure 28. – Continued.



(c) Test item 7, simulated takeoff.

Figure 28. – Continued.



(d) Test item 4, landing.

Figure 28. – Concluded.

	Sta	General location
○	1	5 to 6 miles from airport
○'	2	5 to 6 miles from airport
△	6	3 to 4 miles from airport
△'	10	3 to 4 miles from airport
□	7	Within airport boundary
□'	8	Within airport boundary

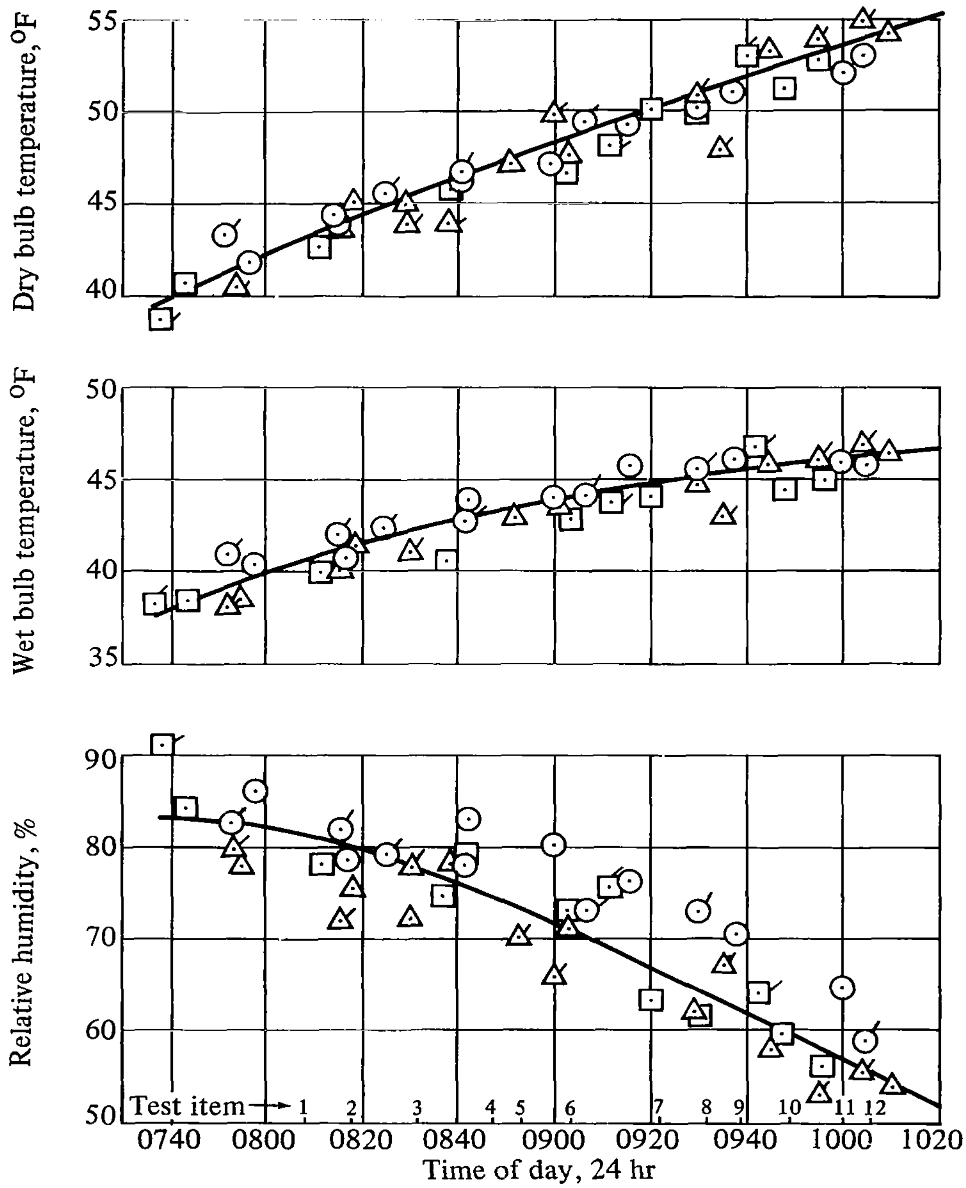
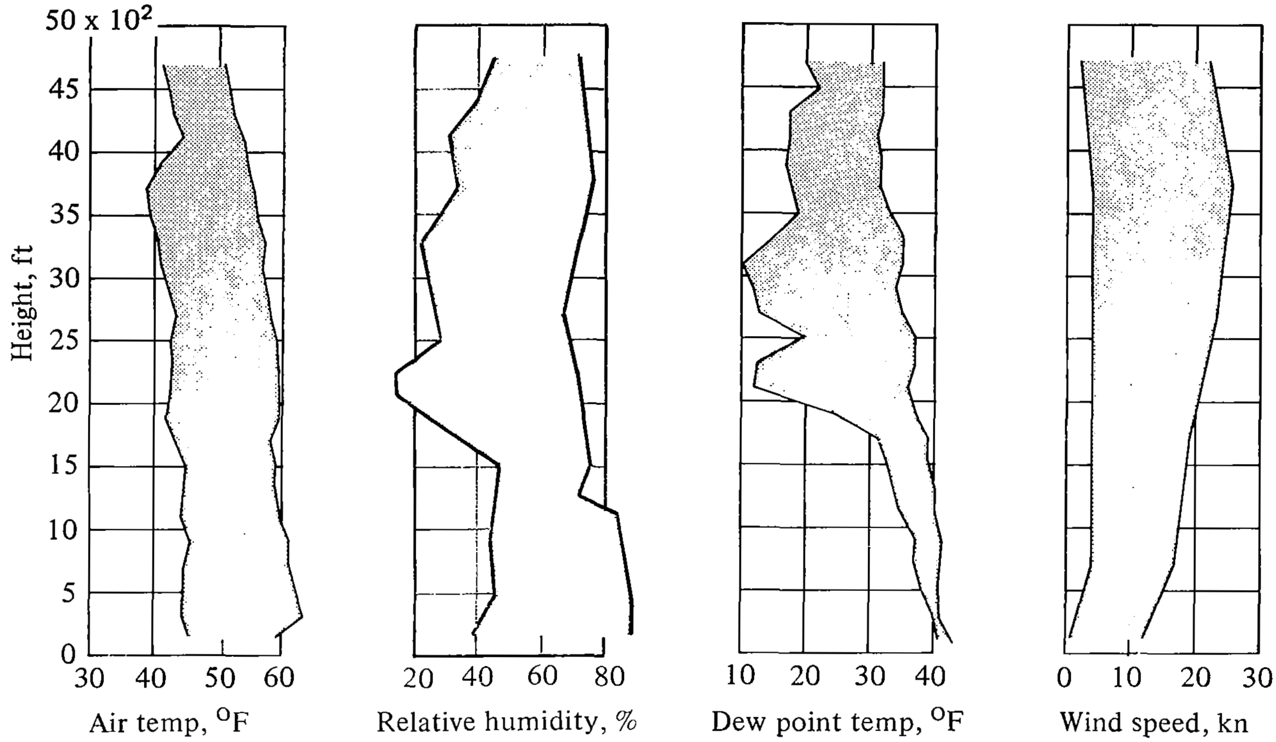
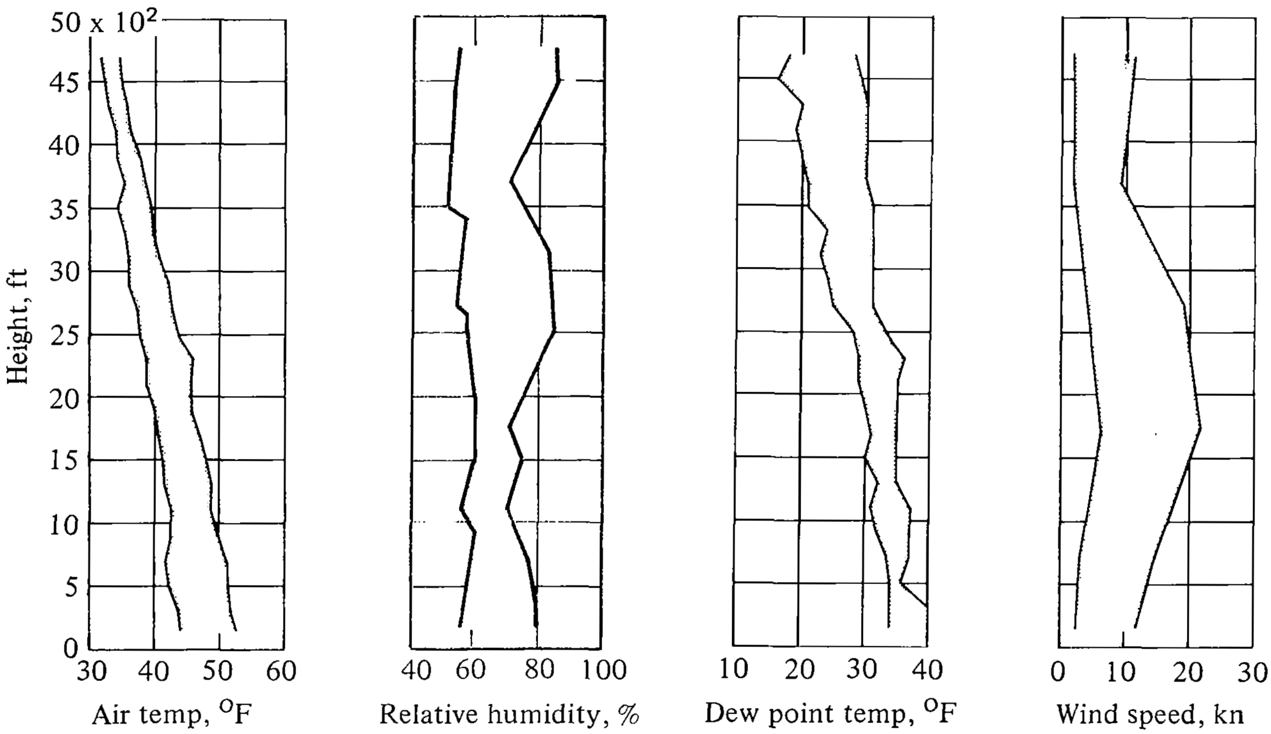


Figure 29. – Illustration of faired surface temperature and humidity measurements.

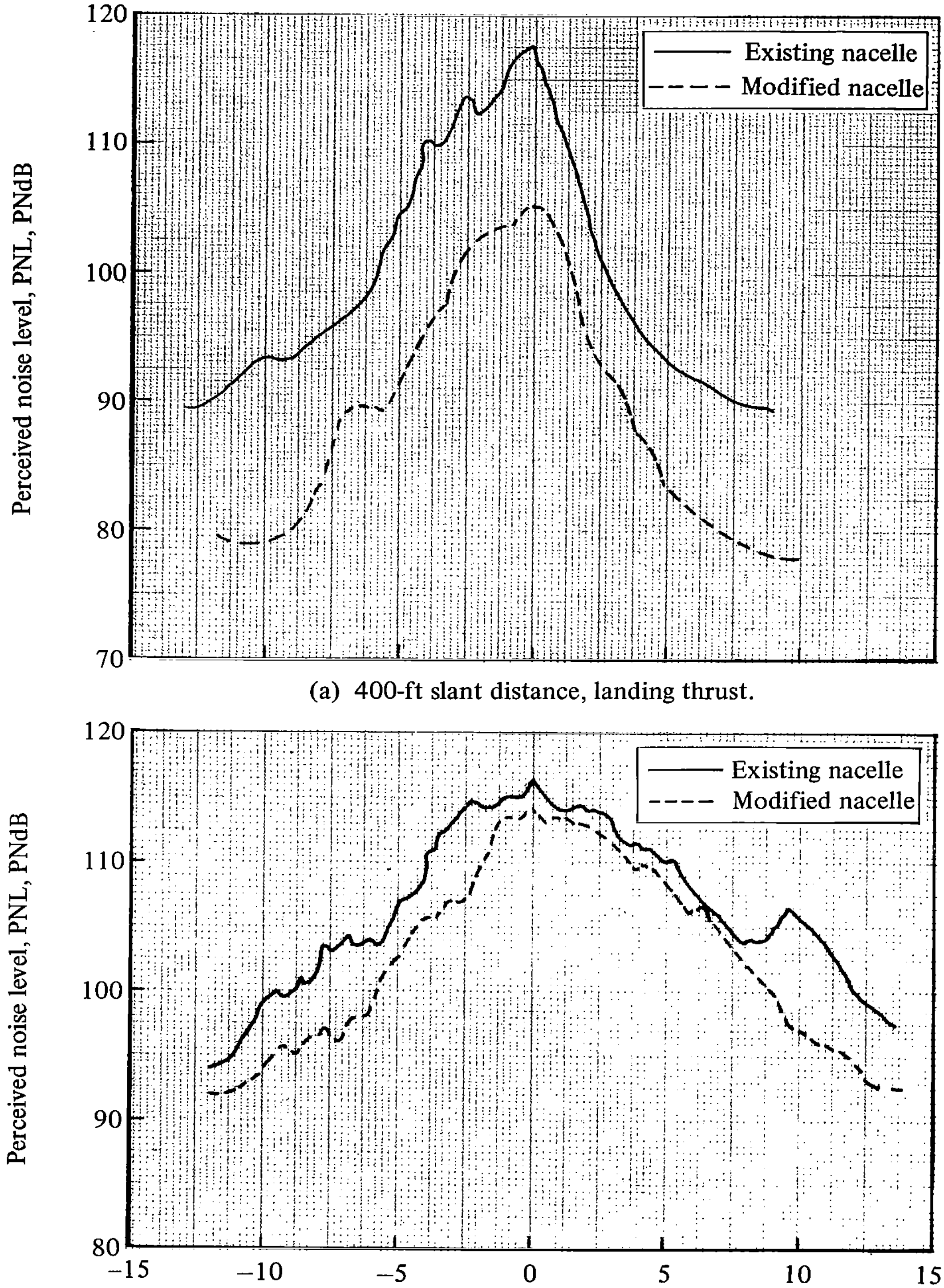


(a) Existing-nacelle test conditions.



(b) Modified-nacelle test conditions.

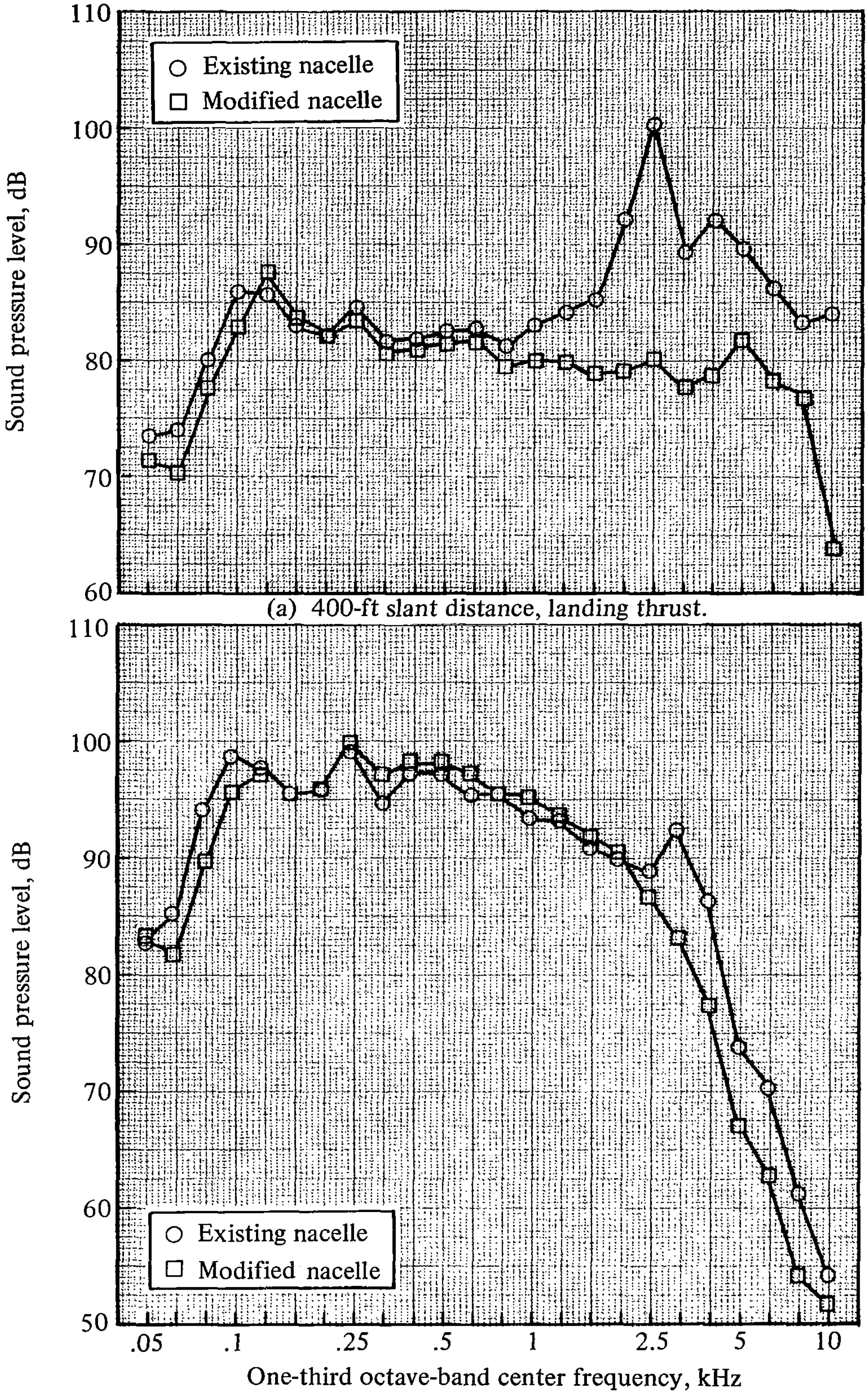
Figure 30. – Range of weather conditions aloft.



(a) 400-ft slant distance, landing thrust.

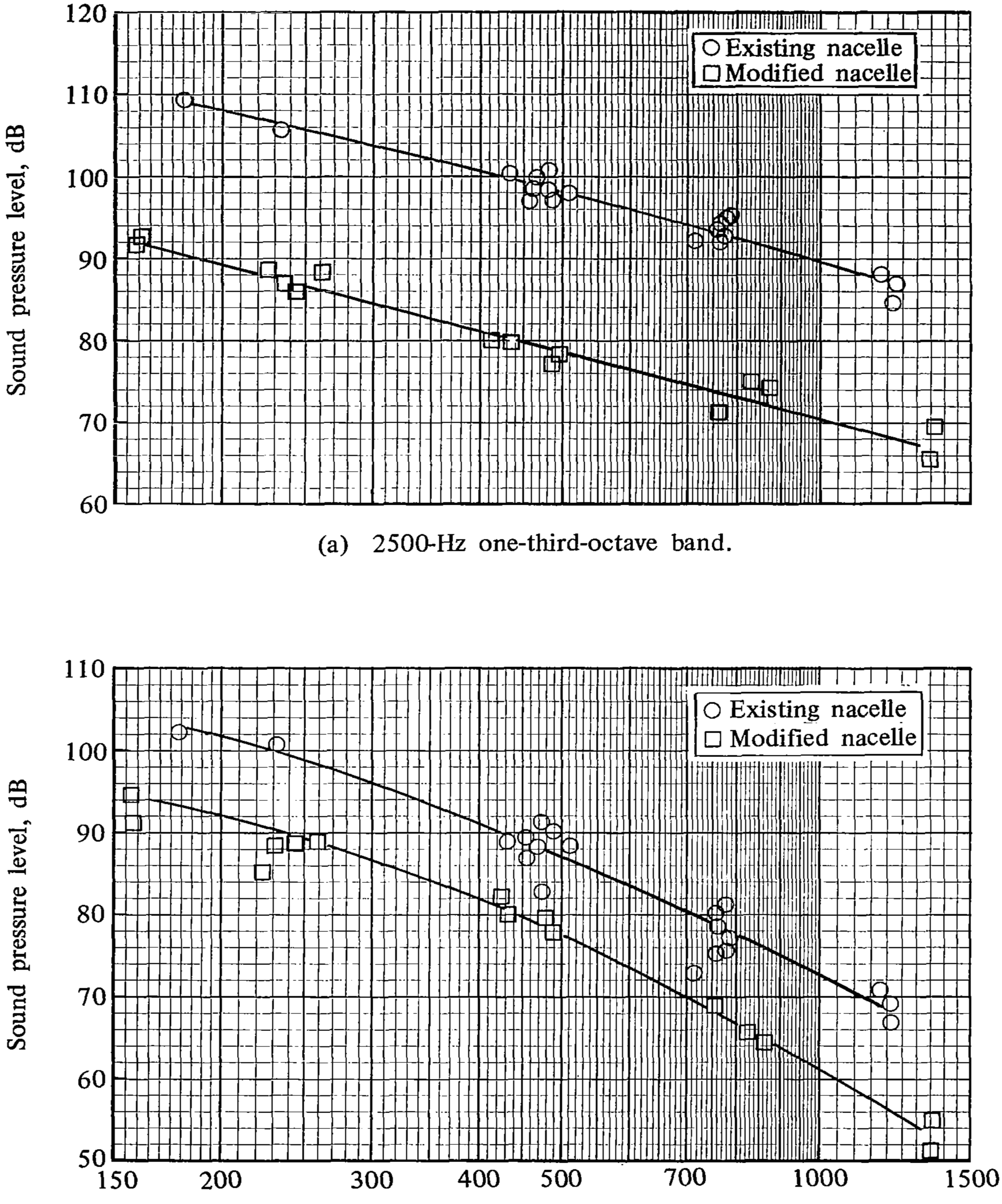
(b) 1000-ft slant distance, takeoff thrust.

Figure 31.—Variation of perceived noise level with time.



(b) 1000-ft slant distance, takeoff thrust.

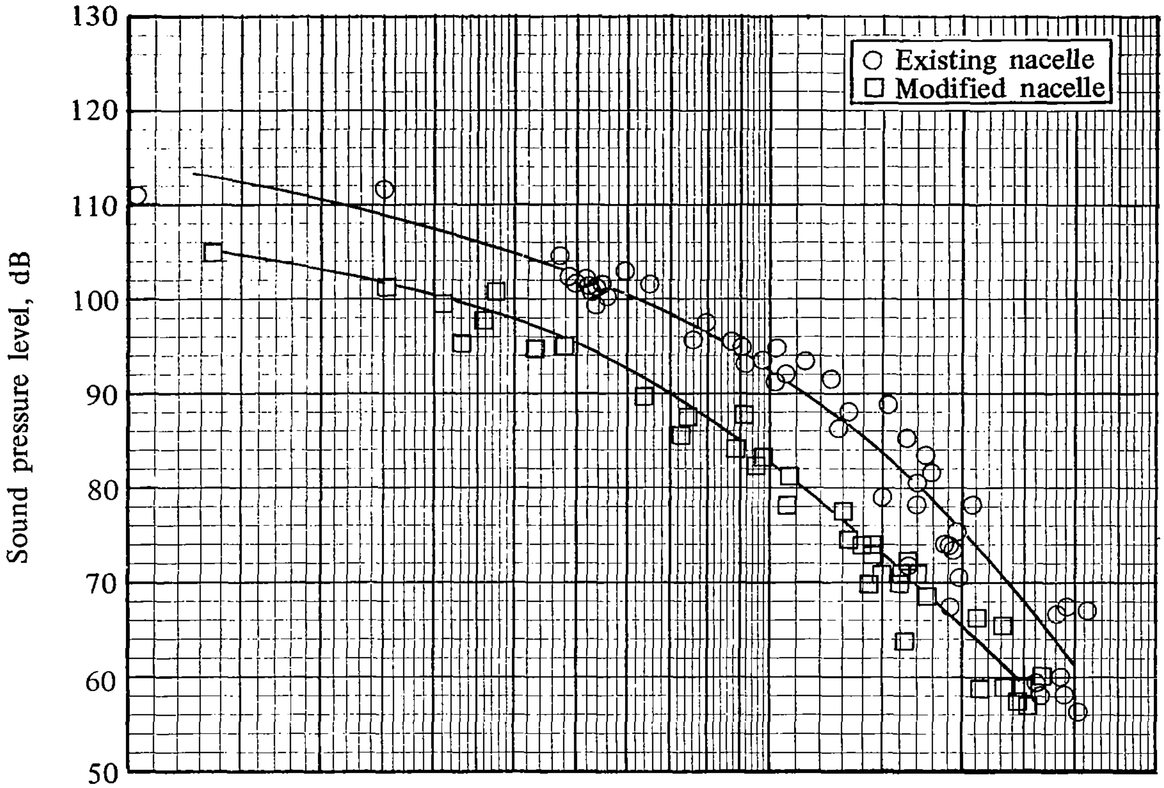
Figure 32. —Sound pressure level spectra at time of PNLM.



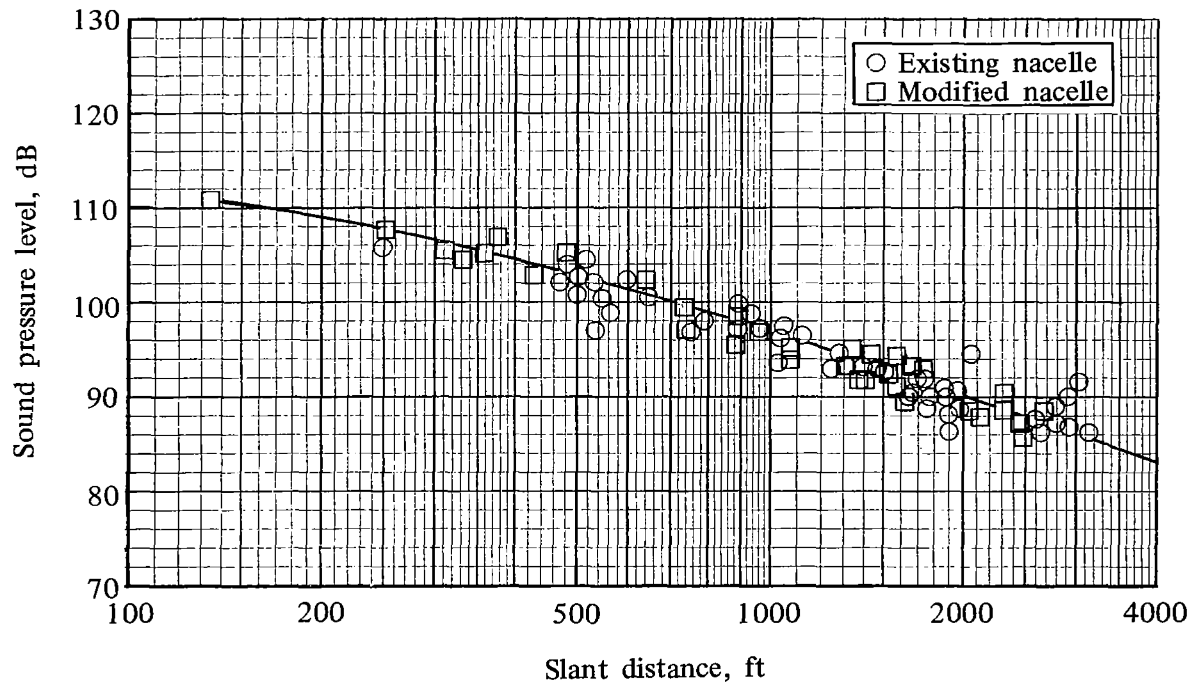
(a) 2500-Hz one-third-octave band.

(b) 5000-Hz one-third octave-band.

Figure 33. – SPL at time of PNLM for landing-approach thrust.

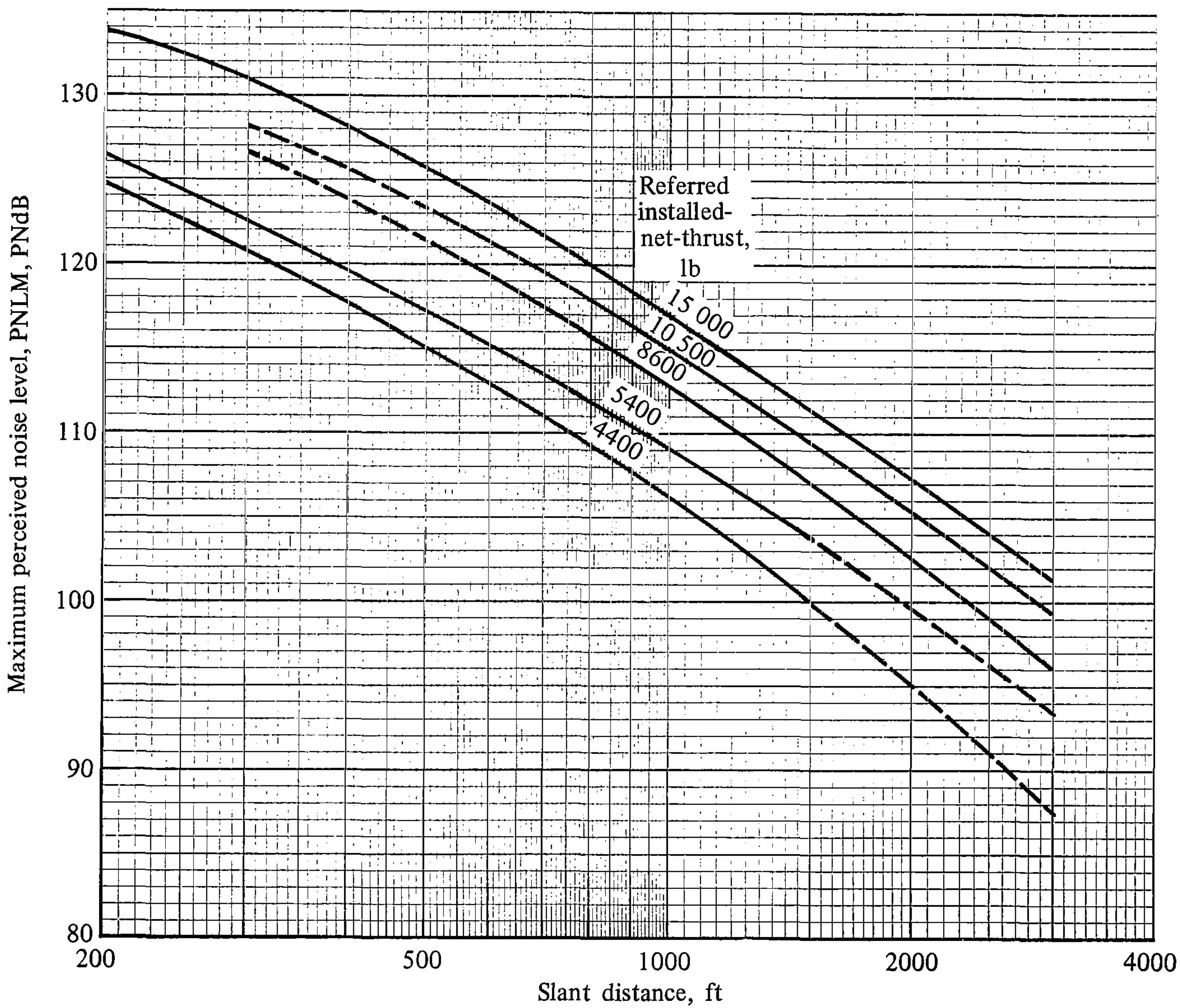


(a) 3150-Hz one-third octave band.



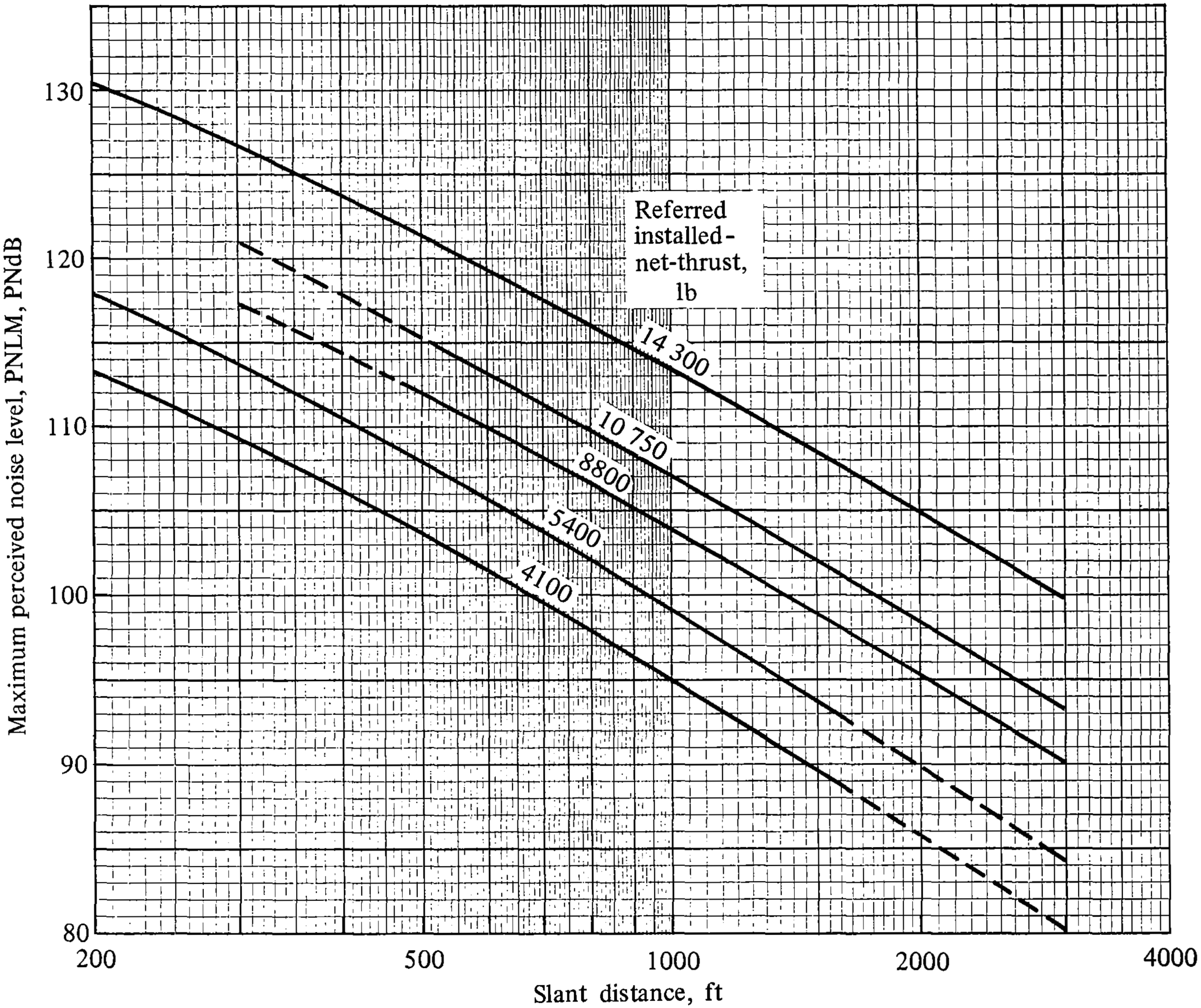
(b) 315-Hz one-third octave band.

Figure 34. – SPL at time of PNLM for takeoff thrust.



(a) Existing nacelle.

Figure 35.—Maximum perceived noise level without atmospheric absorption corrections.



(b) Modified nacelle.

Figure 35. – Concluded.

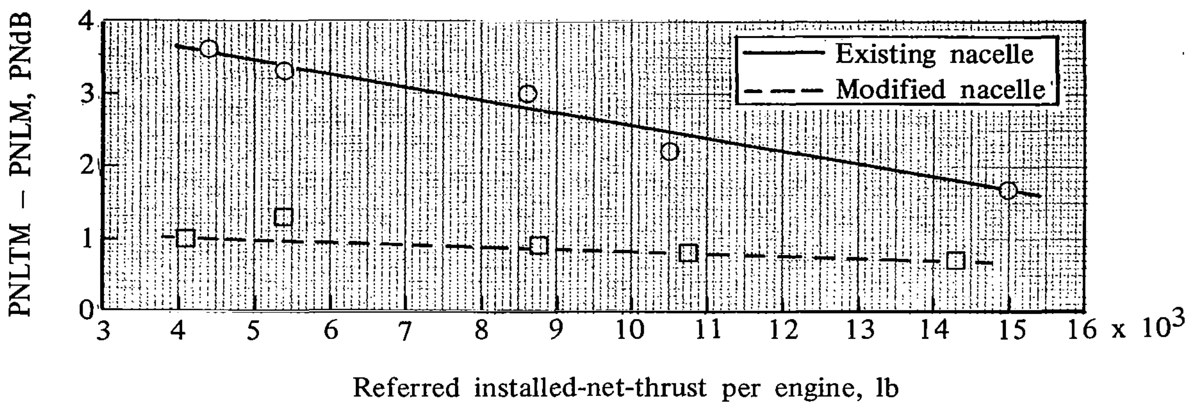


Figure 36.- Difference between PNLTM and PNLM.

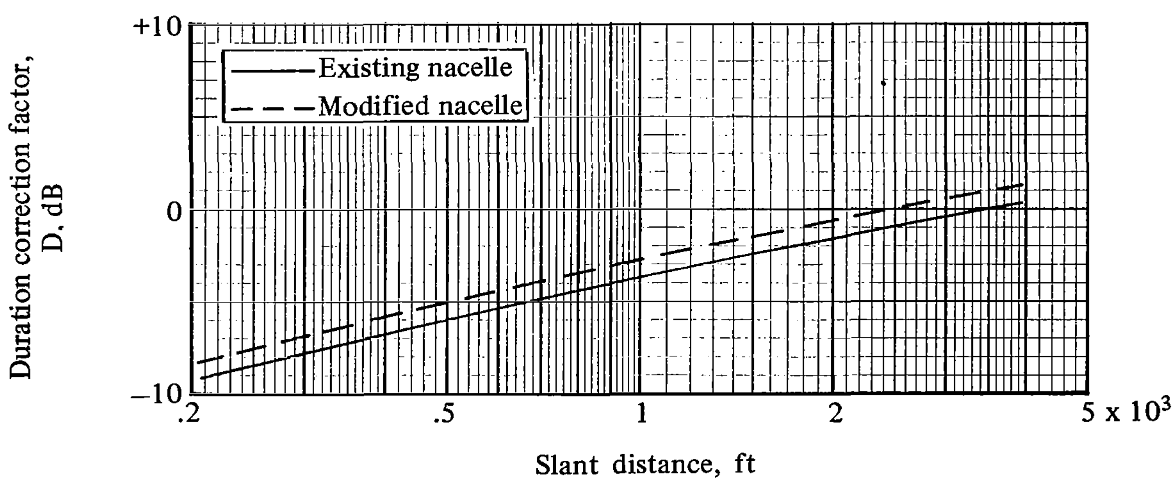
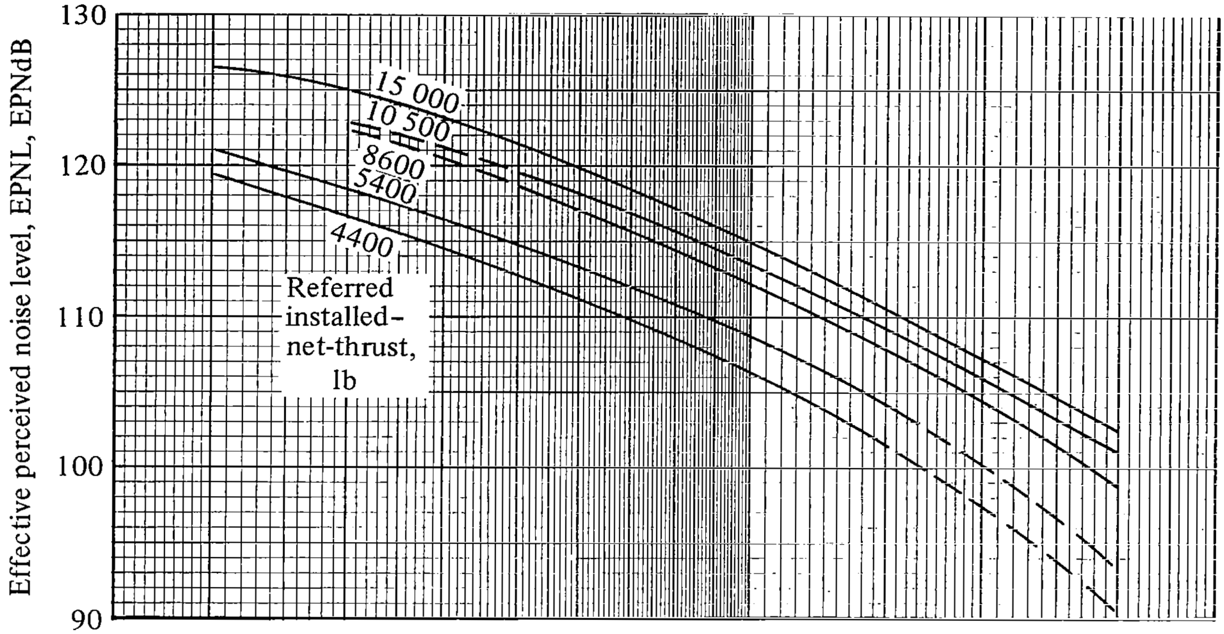
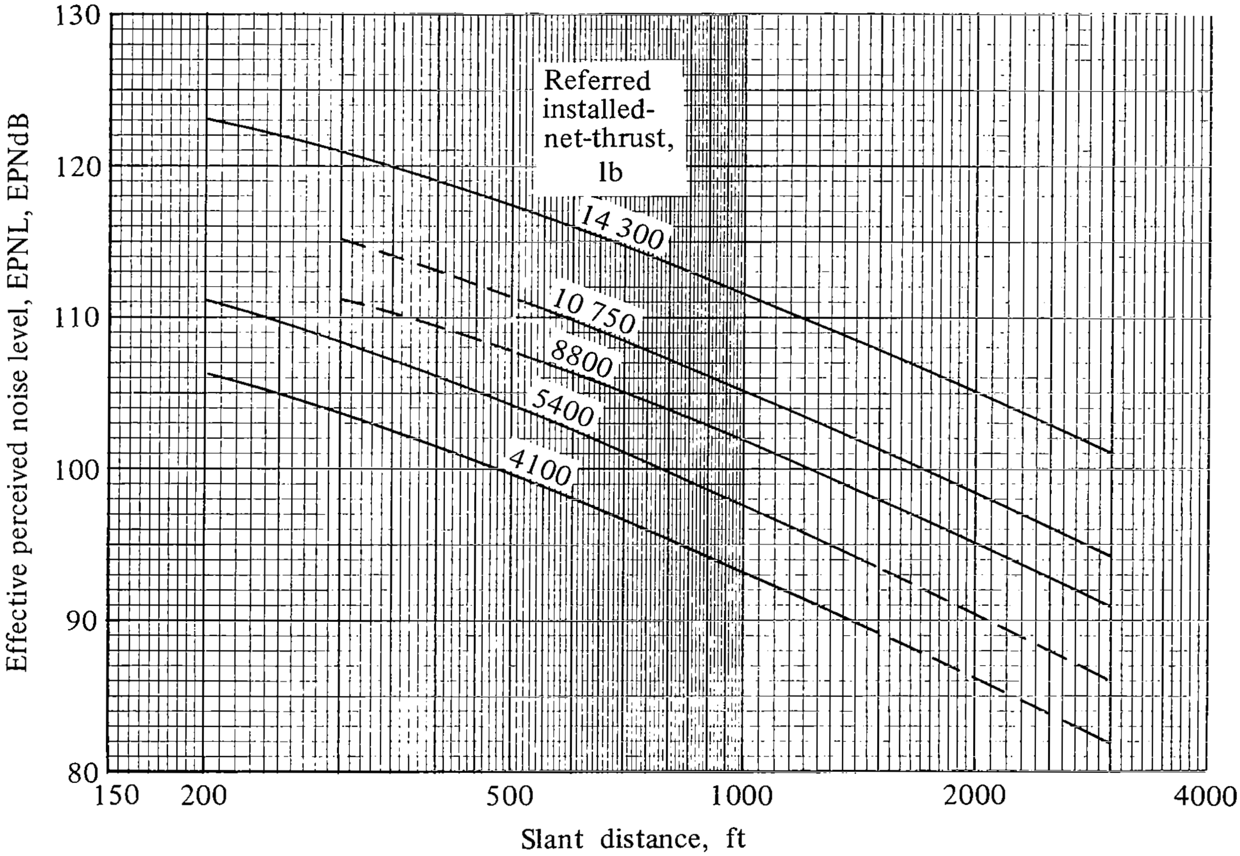


Figure 37. – Duration-correction factors.

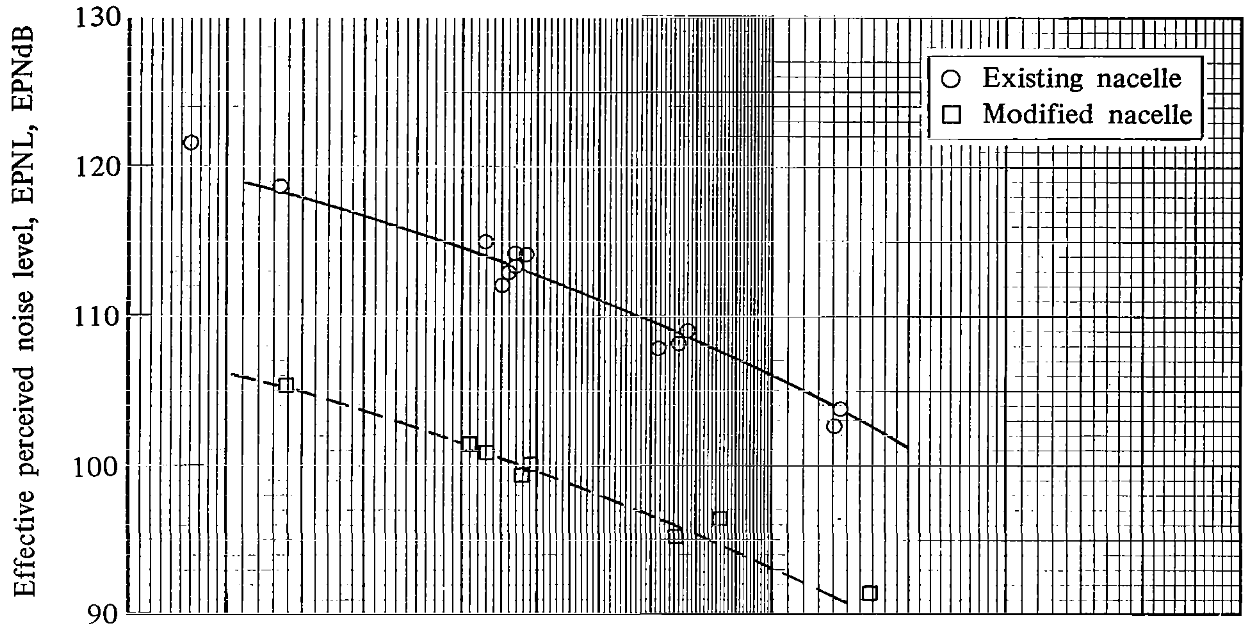


(a) Existing nacelle.

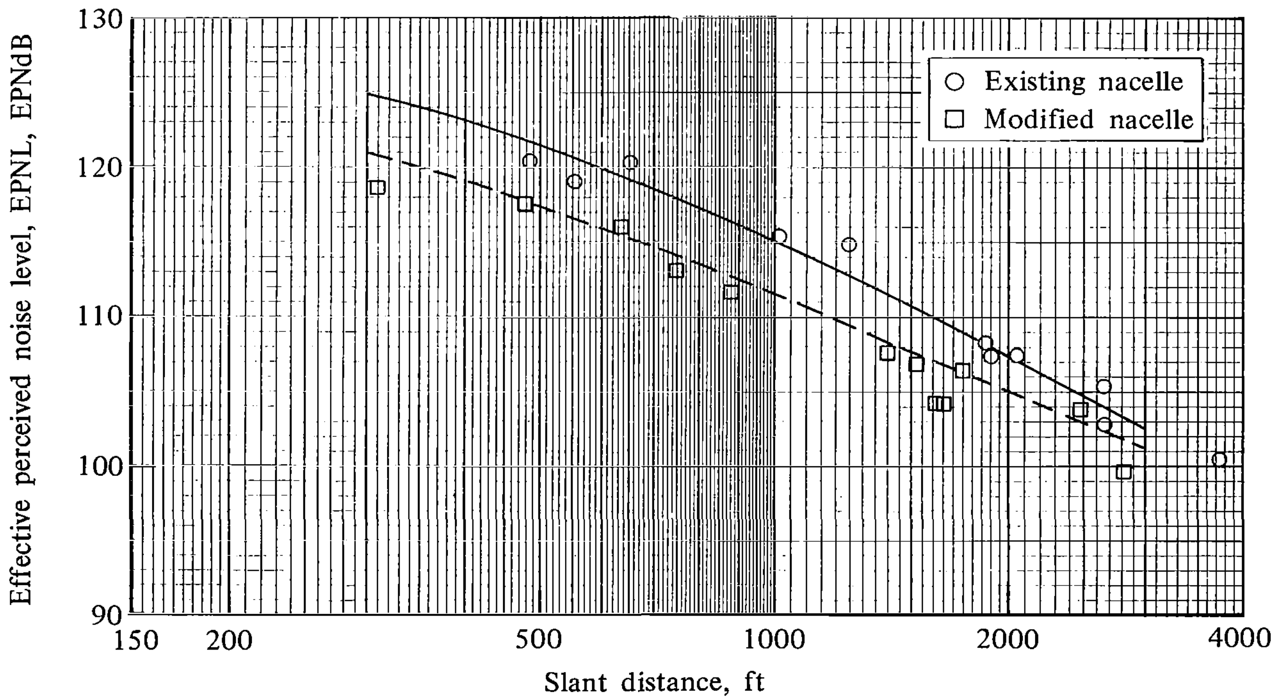


(b) Modified nacelle.

Figure 38. – Effective perceived noise levels for test-day atmospheric conditions.



(a) Landing thrust setting.



(b) Takeoff thrust setting.

Figure 39. – Comparable single-point and generalized EPNLs.

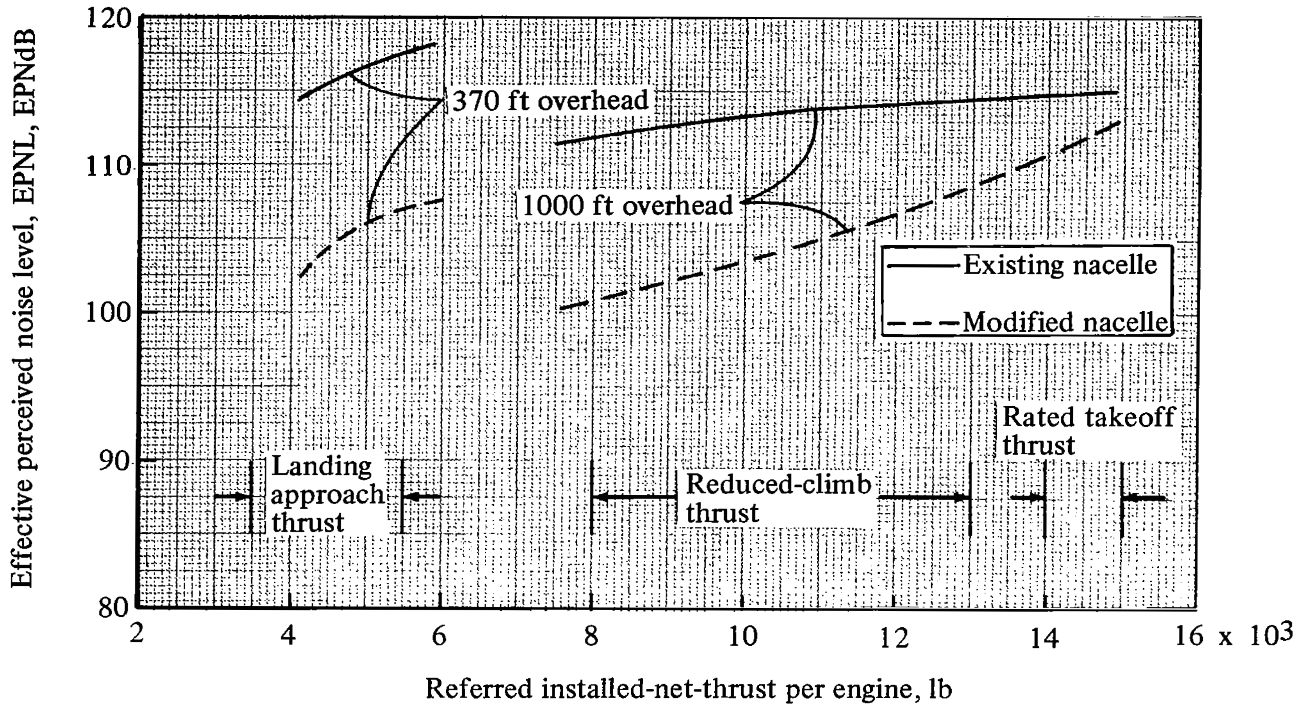


Figure 40.—EPNLs at 370 ft for landing-approach thrusts and at 1000 ft for climbout thrusts.

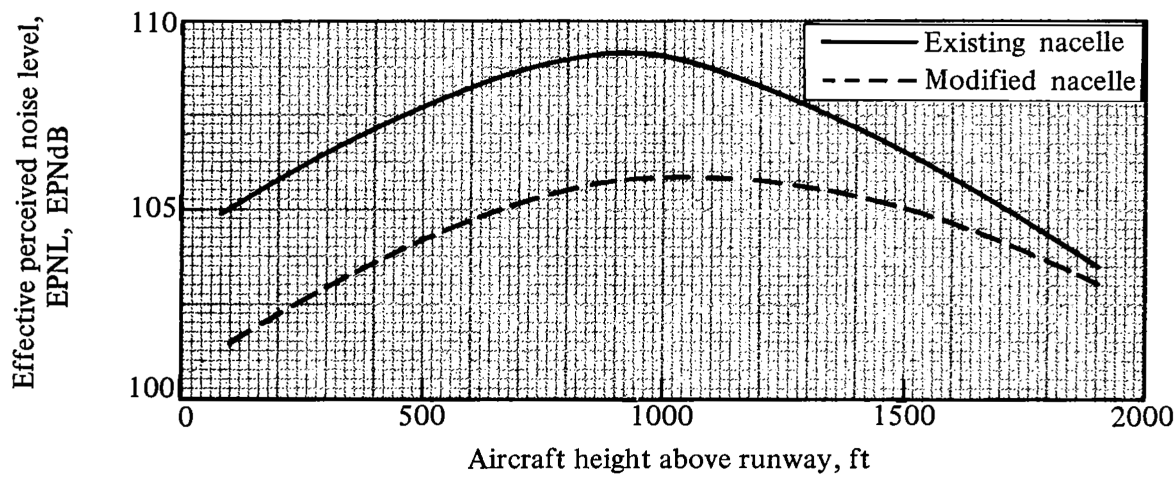
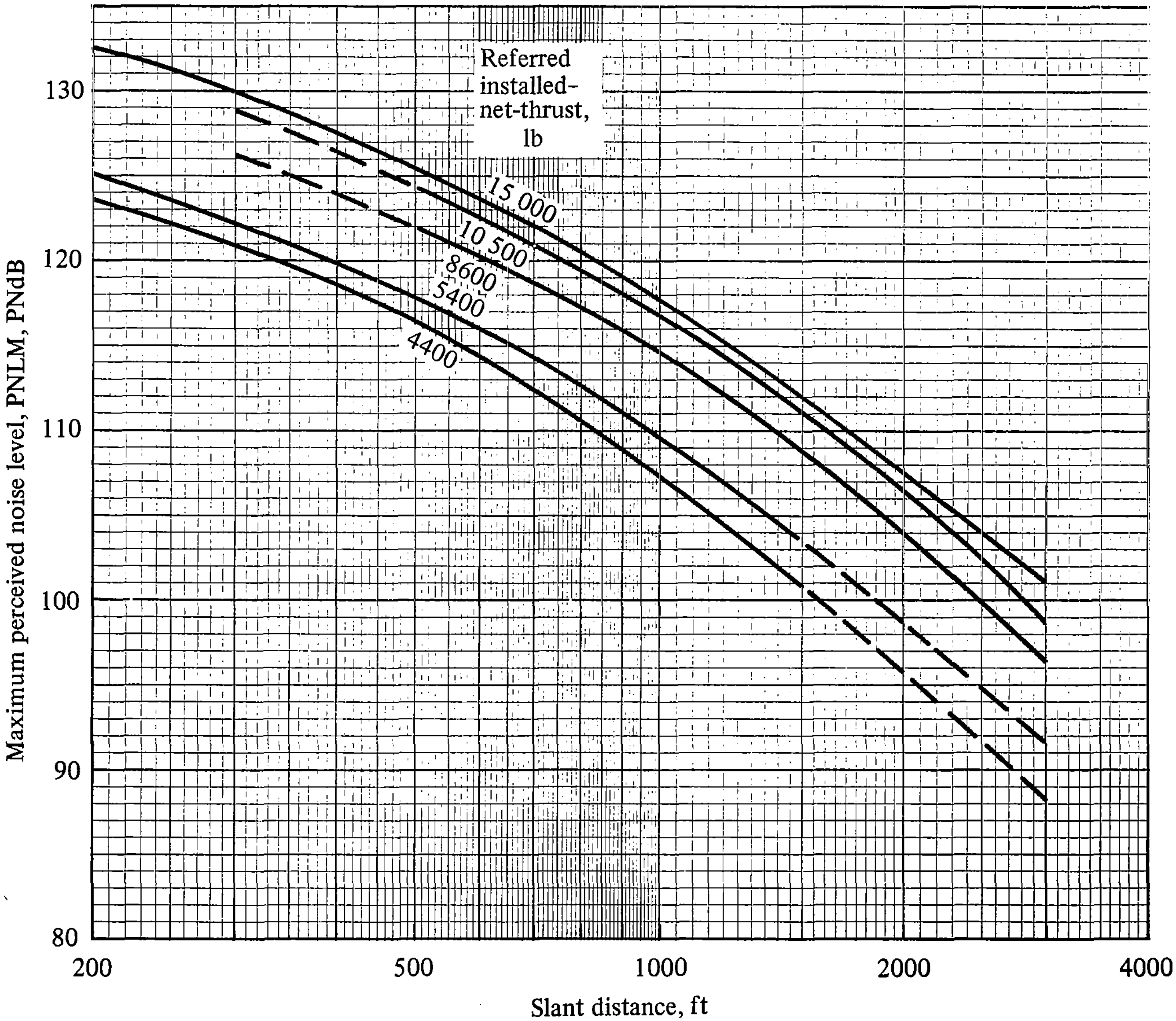
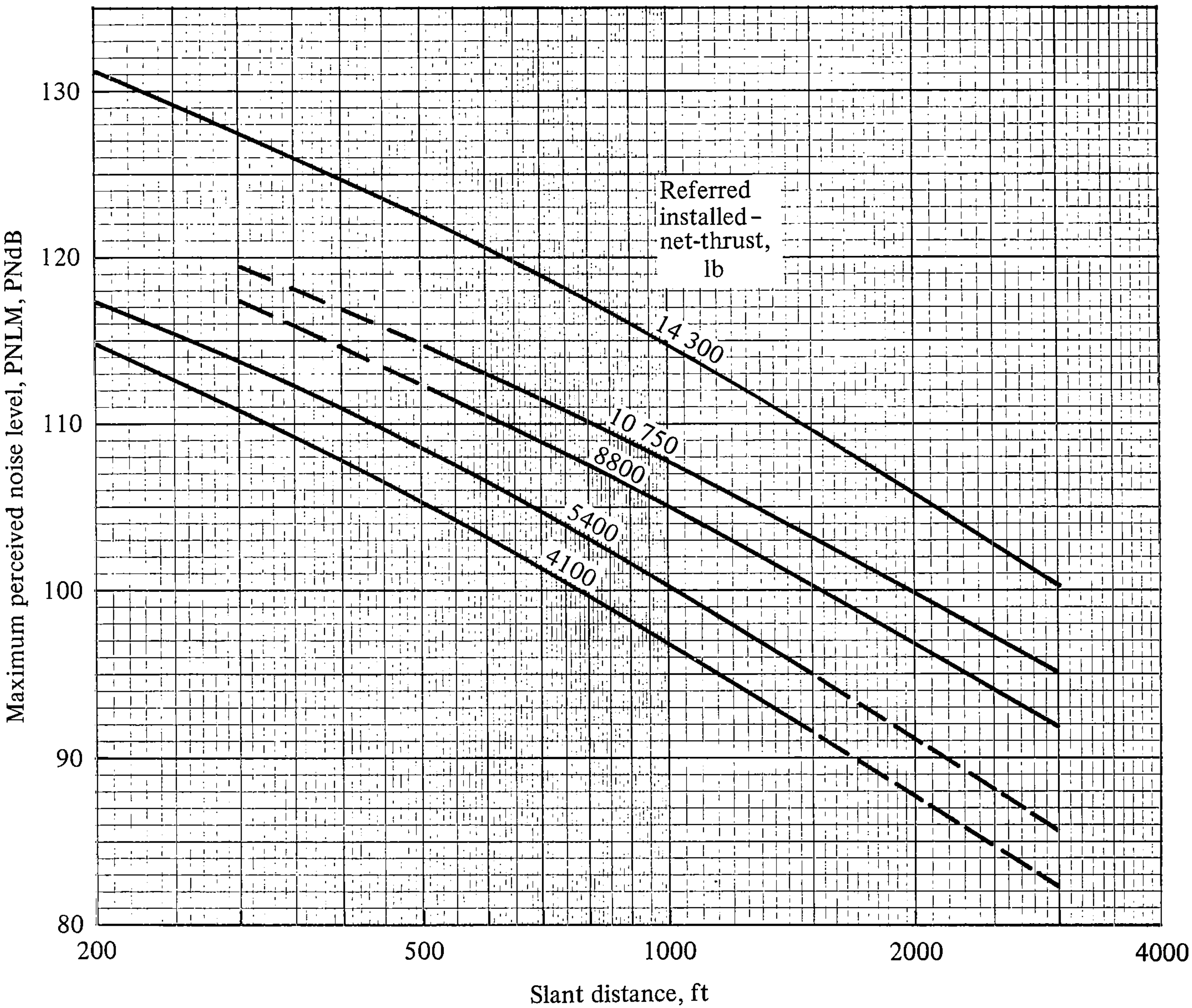


Figure 41.—EPNL at 1500 ft to the side of the flight path for takeoff at 325 000-lb gross weight.



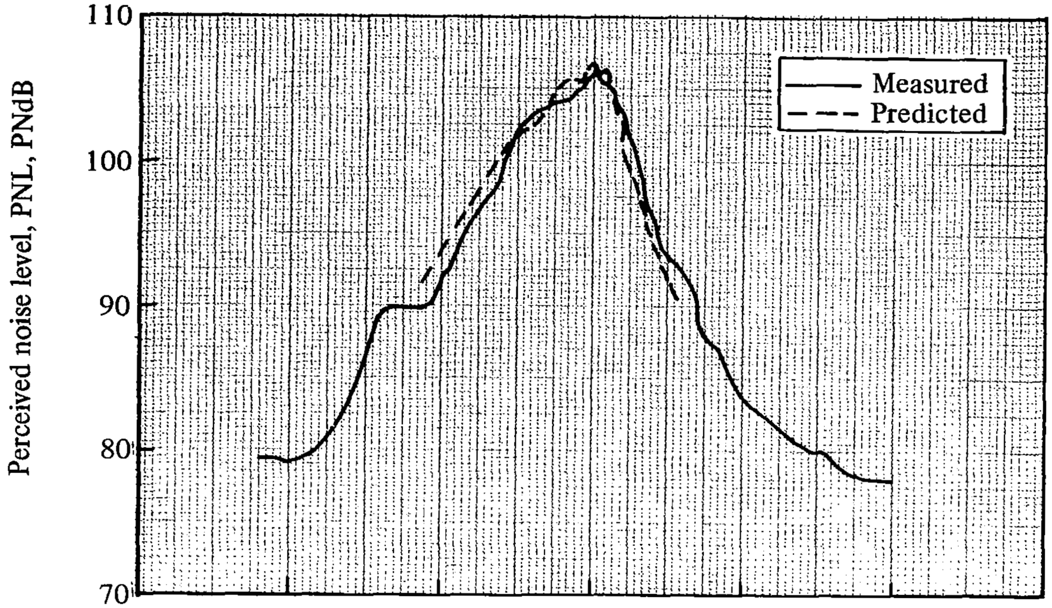
(a) Existing nacelle.

Figure 42.—Maximum perceived noise level corrected to atmospheric conditions of 59°F and 70 percent relative humidity using SAE ARP 866.

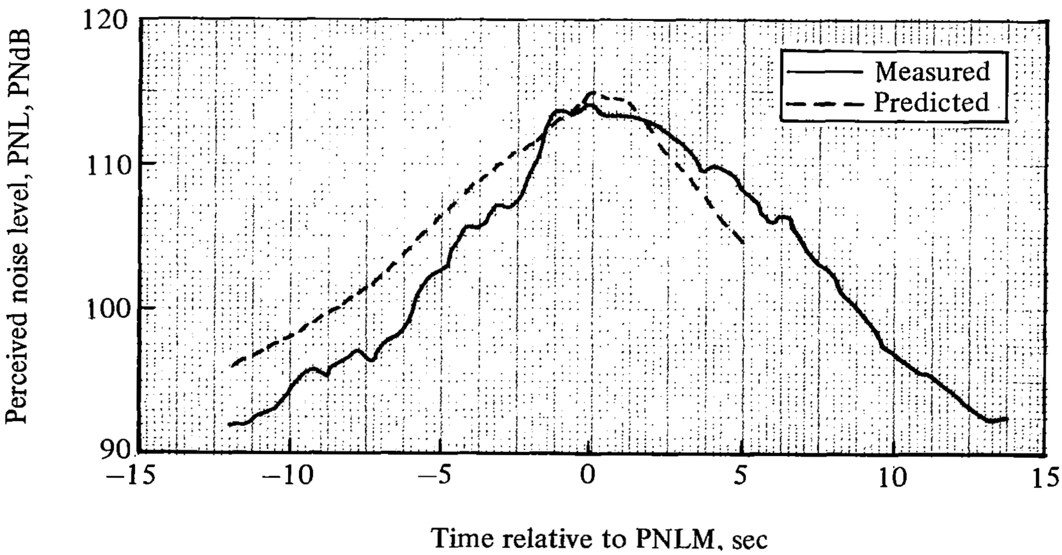


(b) Modified nacelle.

Figure 42. – Concluded.

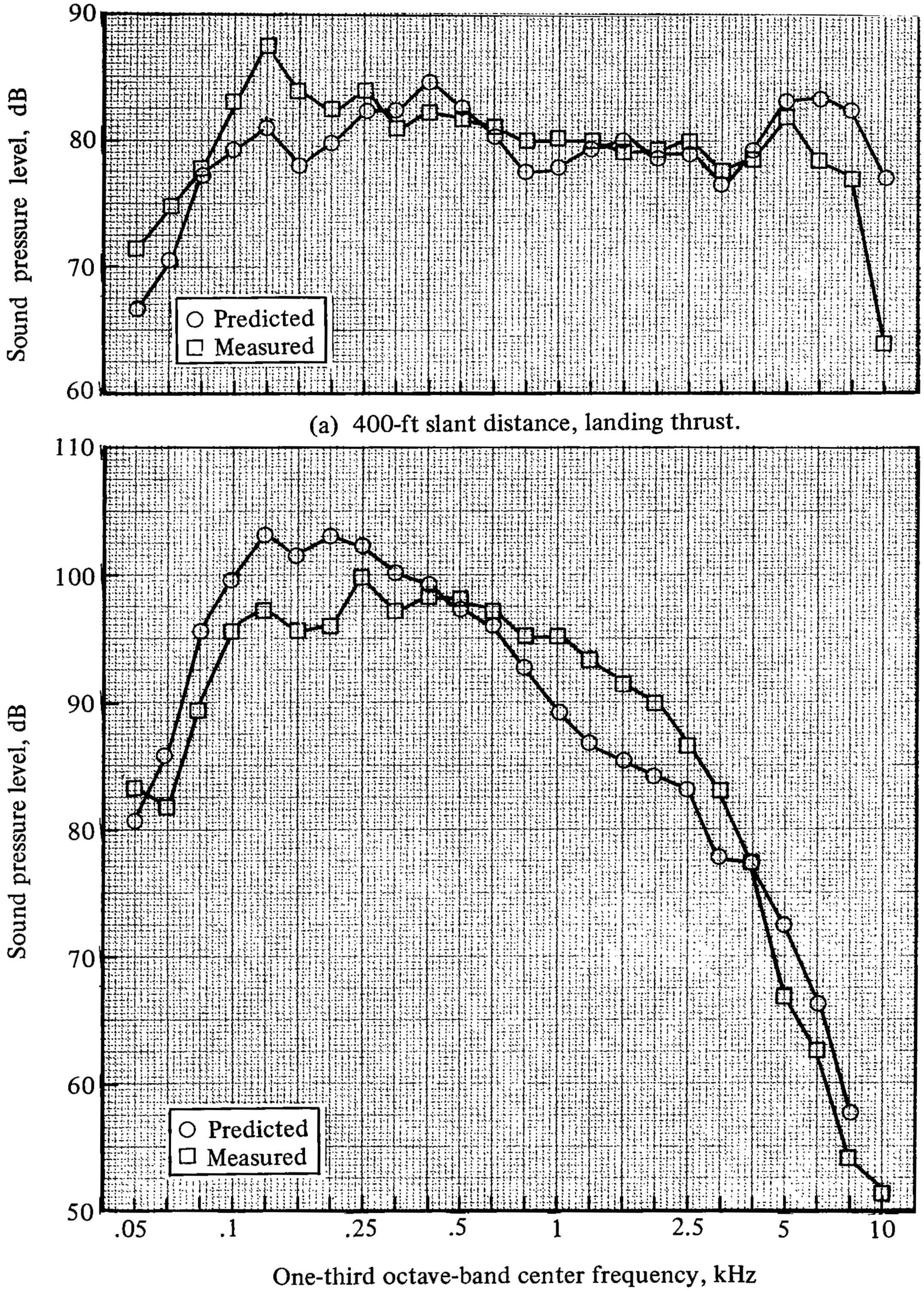


(a) 400-ft slant distance, landing thrust.



(b) 1000-ft slant distance, takeoff thrust.

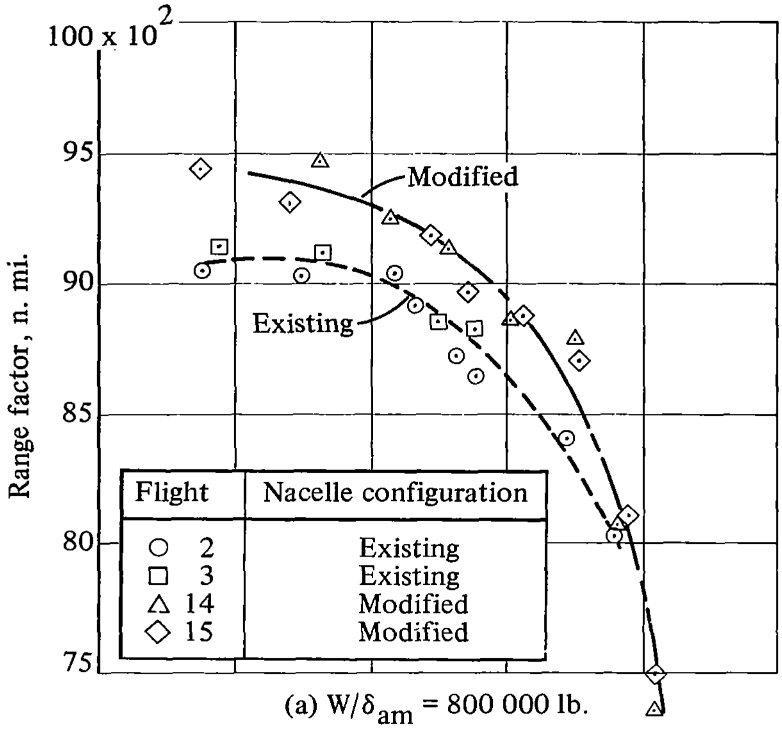
Figure 43.—Measured and predicted variation of perceived noise level with time for the modified nacelle.



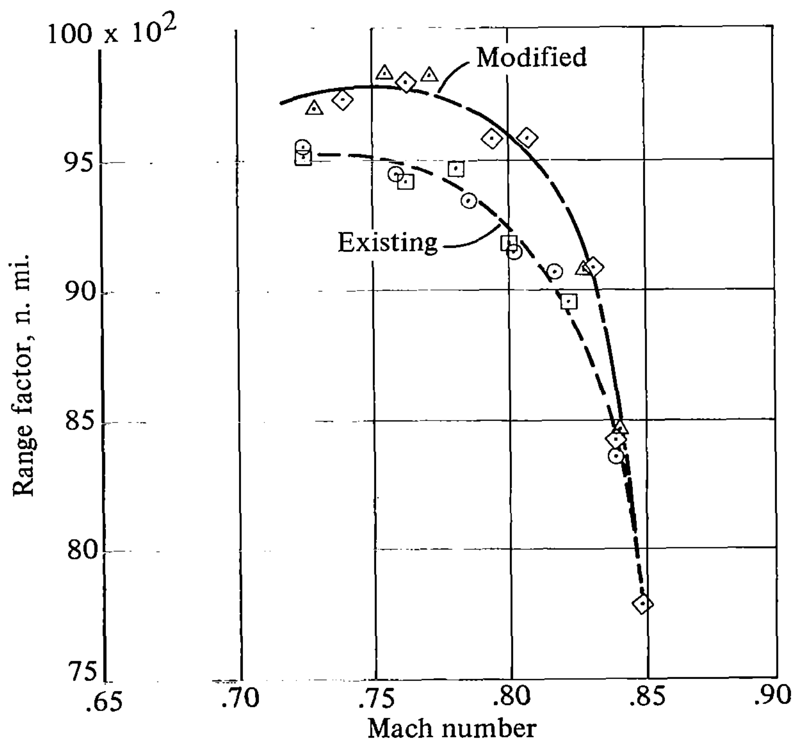
(a) 400-ft slant distance, landing thrust.

(b) 1000-ft slant distance, takeoff thrust.

Figure 44.—Measured and predicted sound pressure level spectra at the time of PNLM for the modified nacelle.

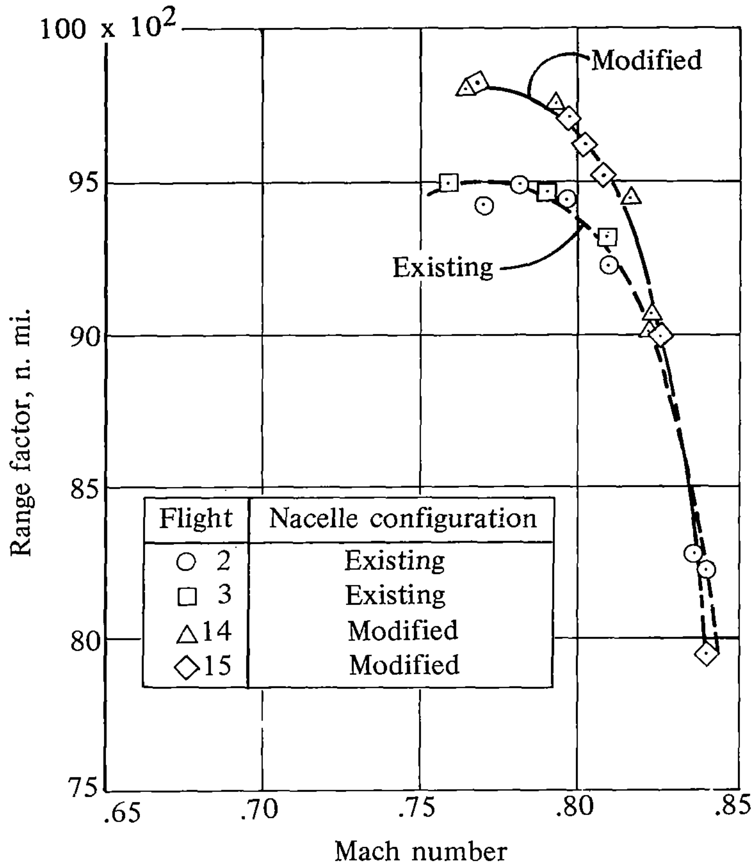


(a) W/δ_{am} = 800 000 lb.



(b) W/δ_{am} = 950 000 lb.

Figure 45. – Range factors for the DC-8-55 test airplane.



(c) W/δ_{am} = 1 100 000 lb.

Figure 45. – Concluded.

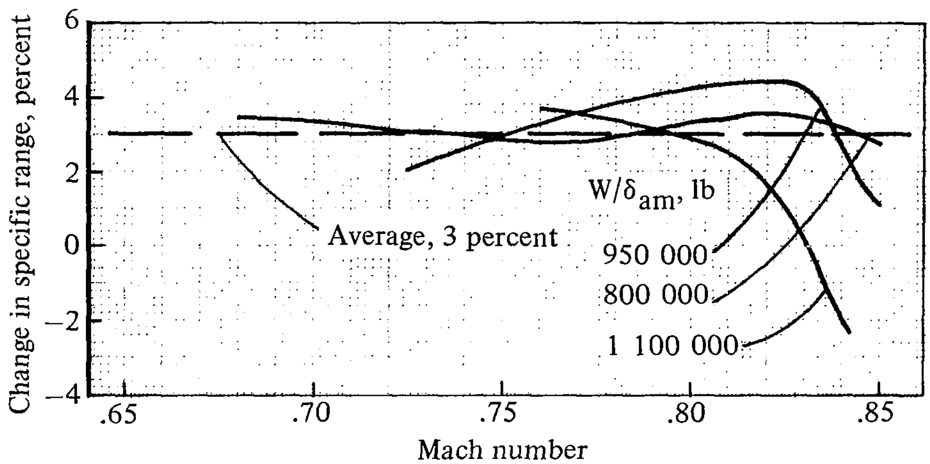
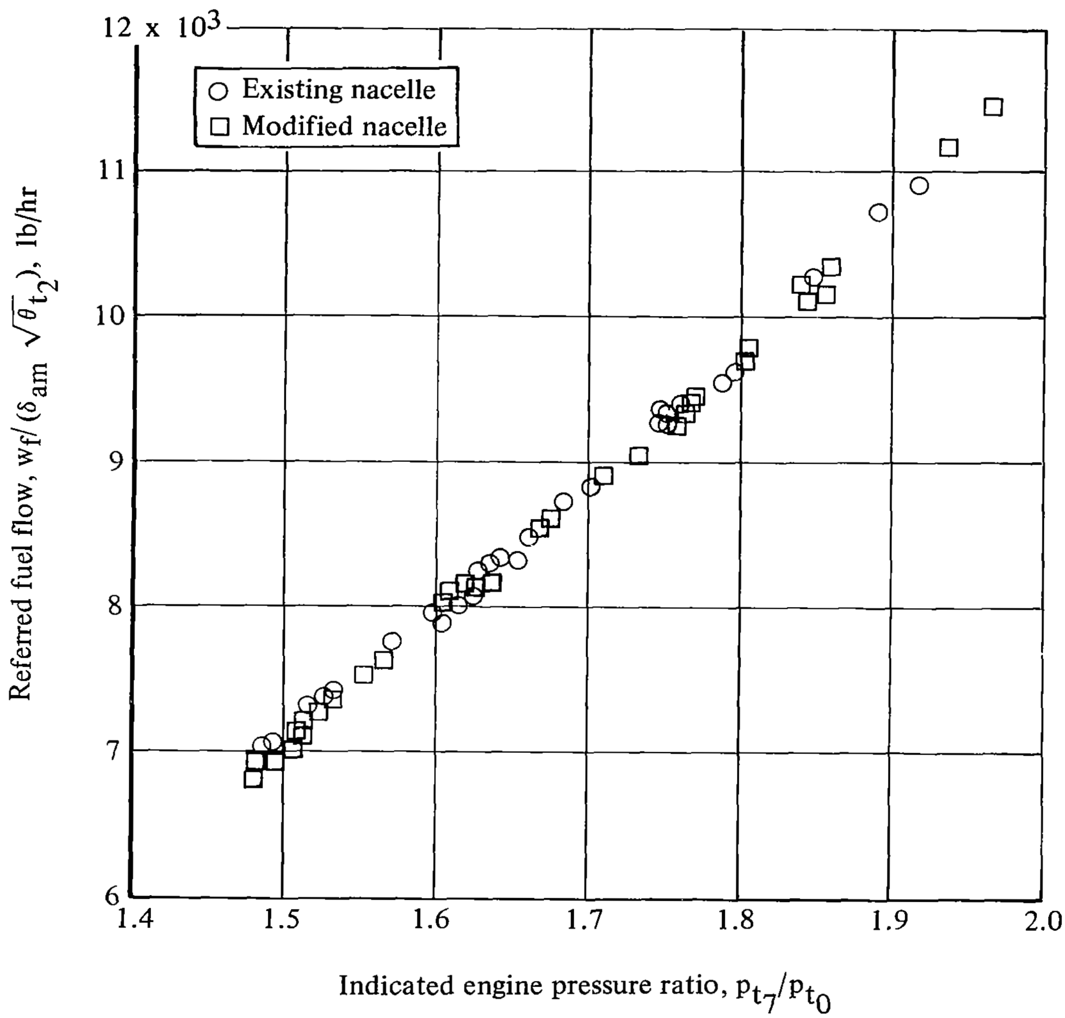
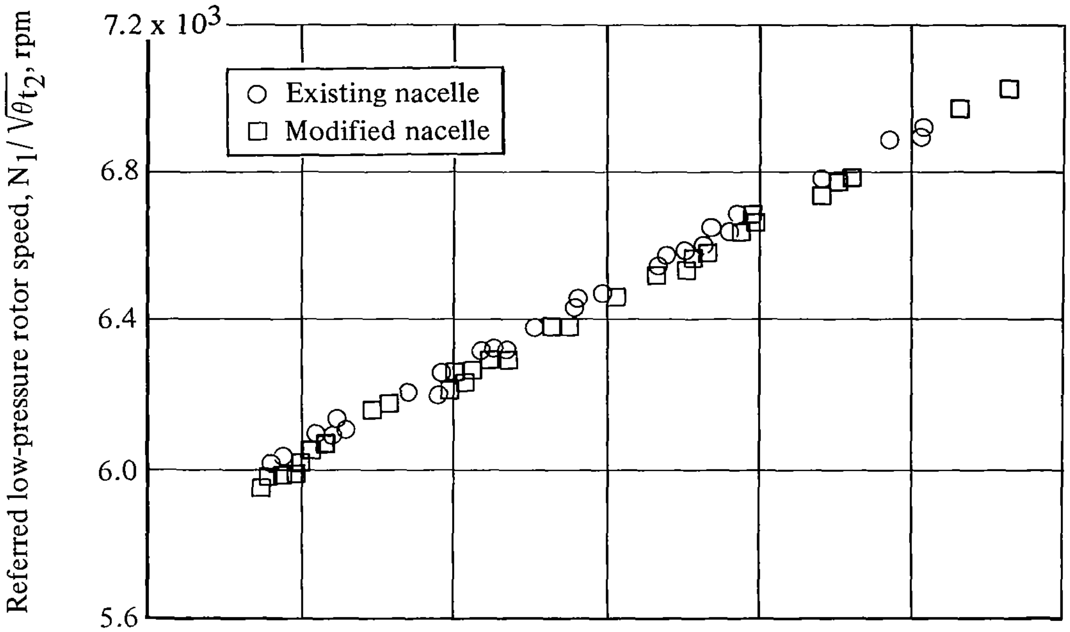


Figure 46. – Effect of modified nacelle on specific range.

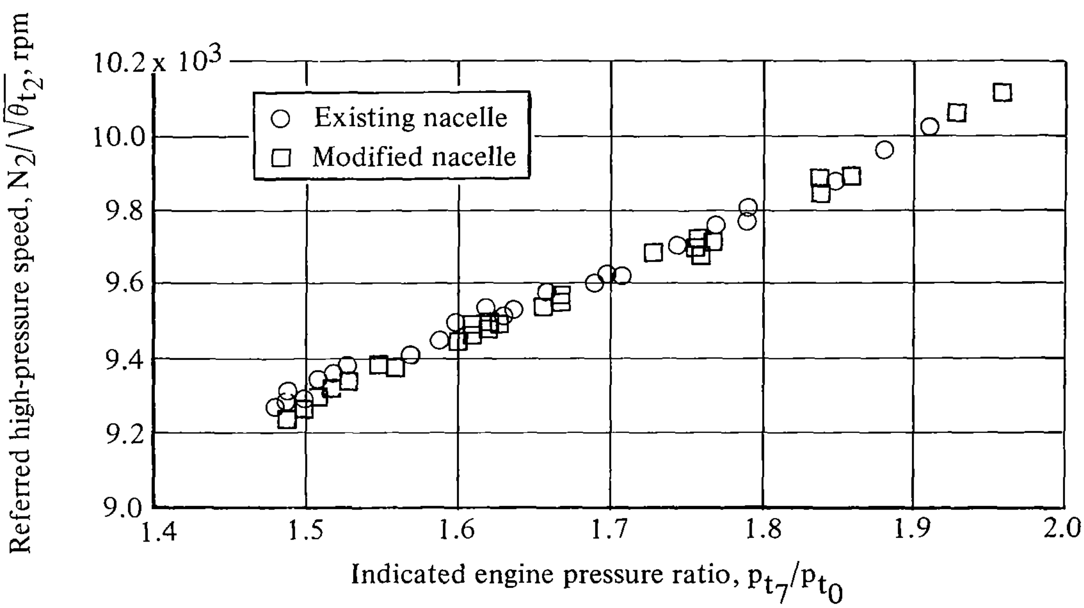


(a) Referred fuel flow.

Figure 47.—Comparison of primary engine parameters.



(b) Referred low-pressure rotor speed.



(c) Referred high-pressure rotor speed.

Figure 47.—Concluded.

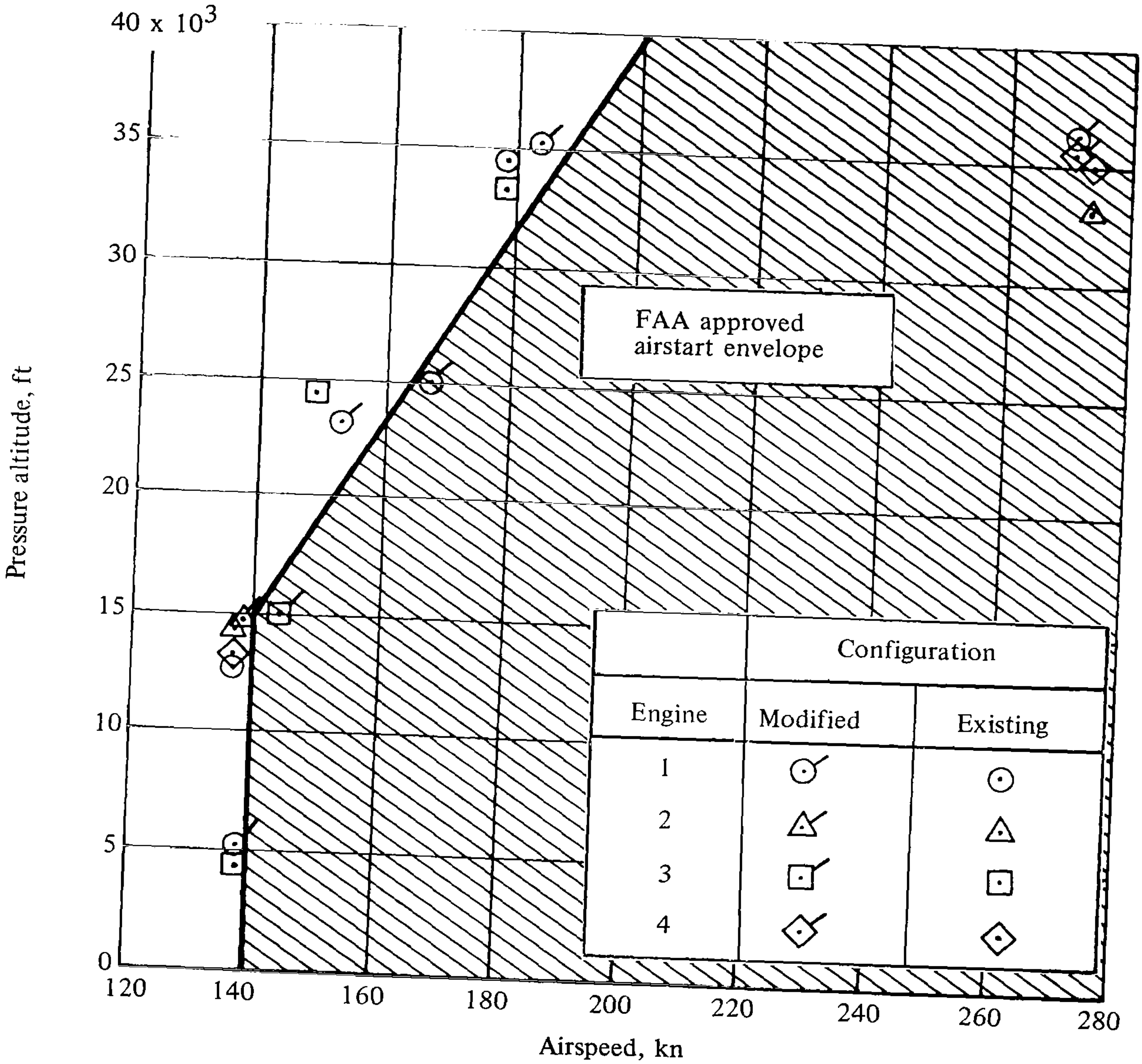


Figure 48. – Engine airstarts performed with the DC-8-55 test airplane.

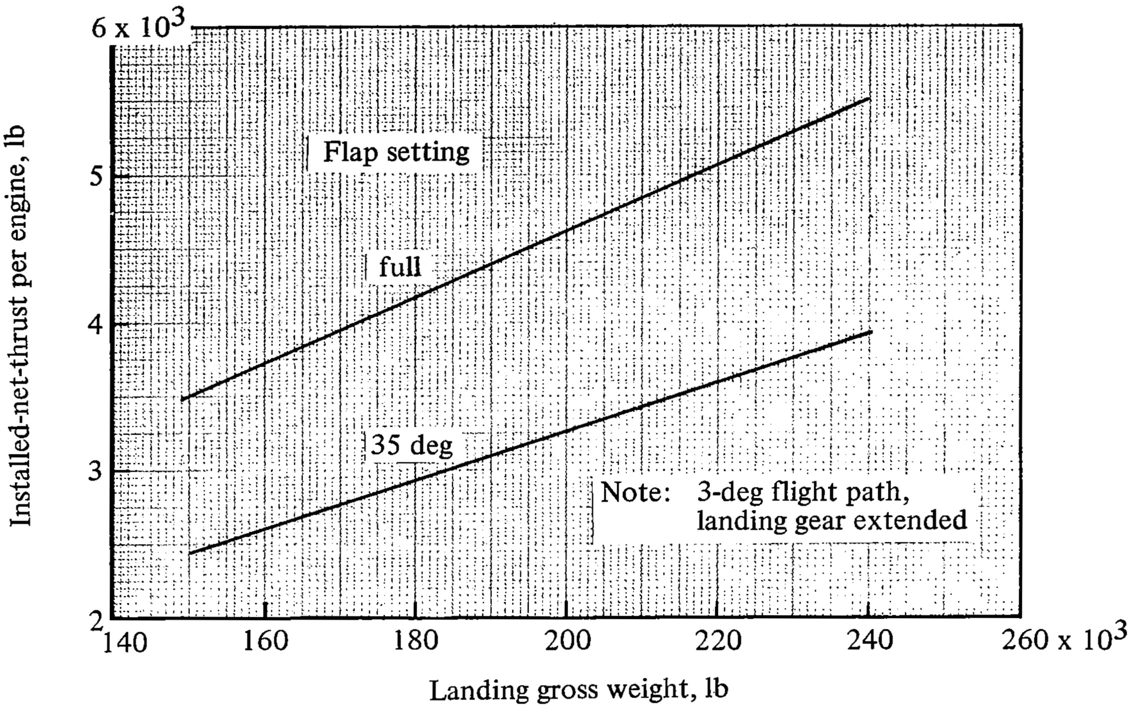


Figure 49. – Thrust required during landing.

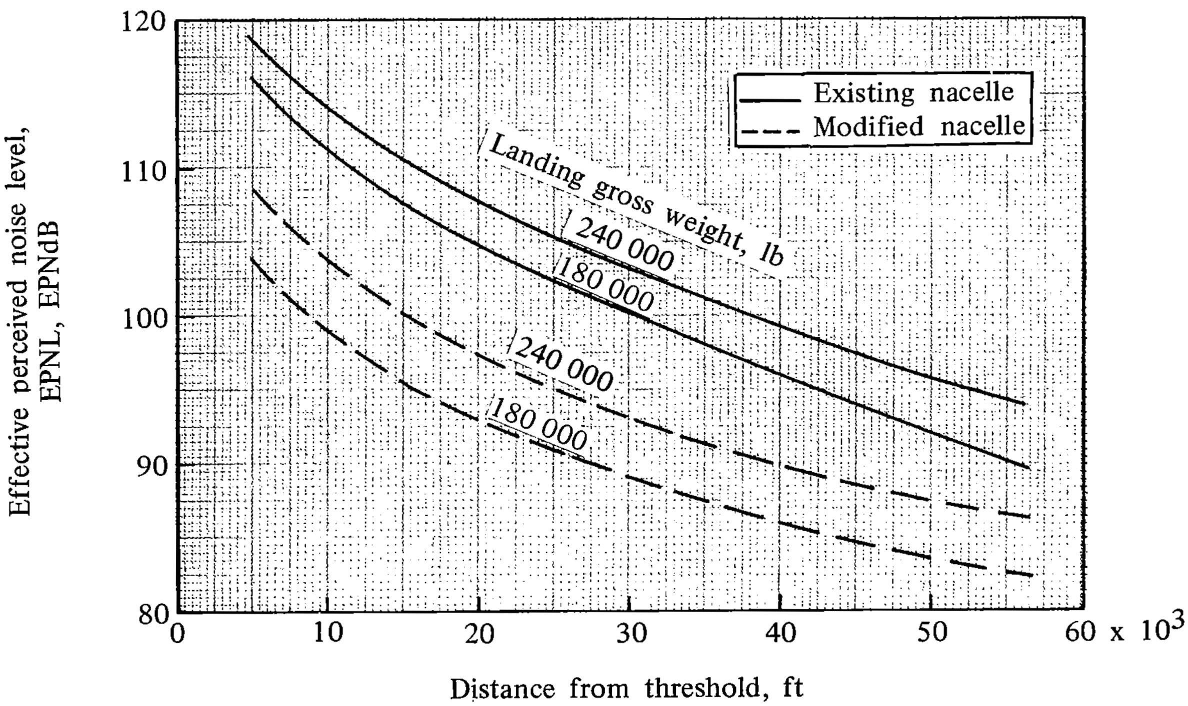


Figure 50. – EPNL under a 3-degree landing-approach flight path; flaps fully extended.

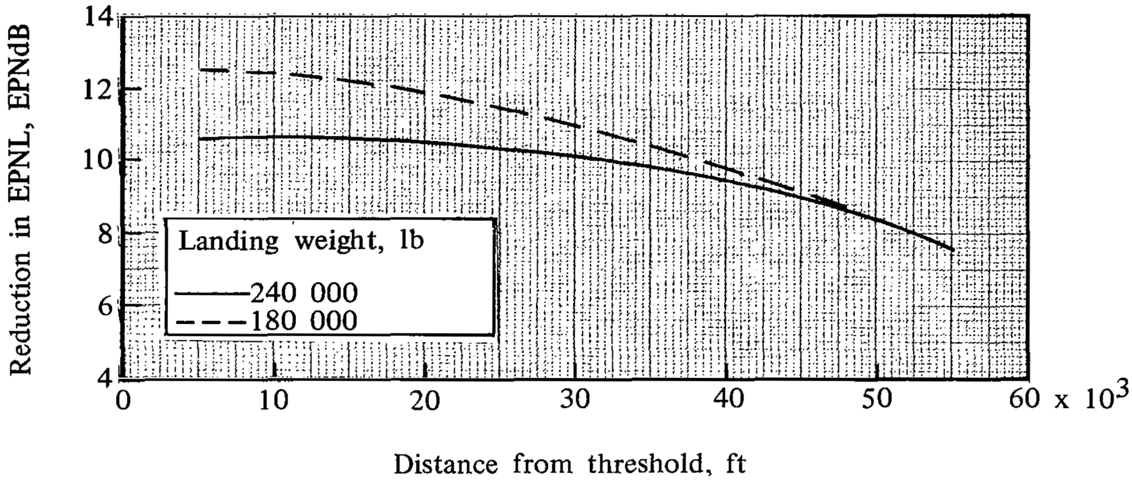


Figure 51. – Reduction in EPNL under 3-degree landing-approach flight path.

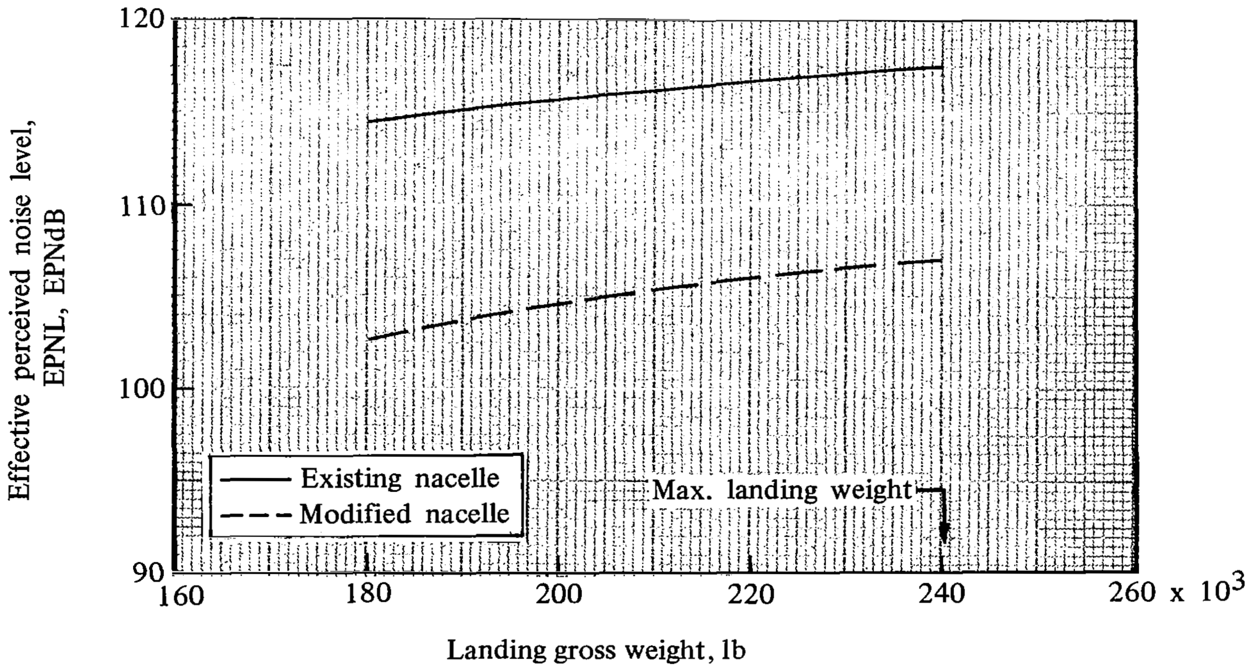


Figure 52. – EPNL at 1 n. mi. from threshold; 3-degree landing-approach flight path.

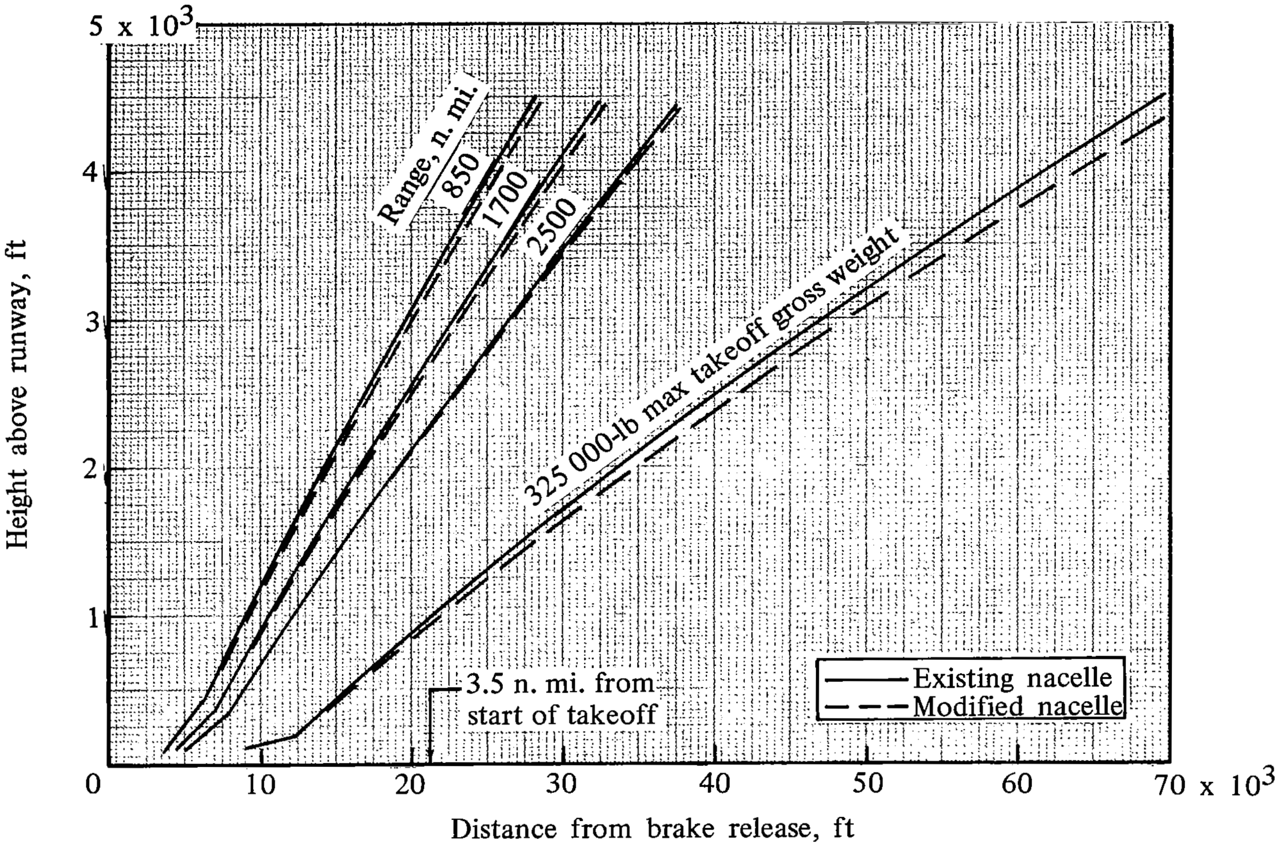


Figure 53. – Takeoff and initial climb paths for the DC-8-55 airplane; V_2 + 10 kn climb airspeed; landing gear retracted; 25-degree flap setting.

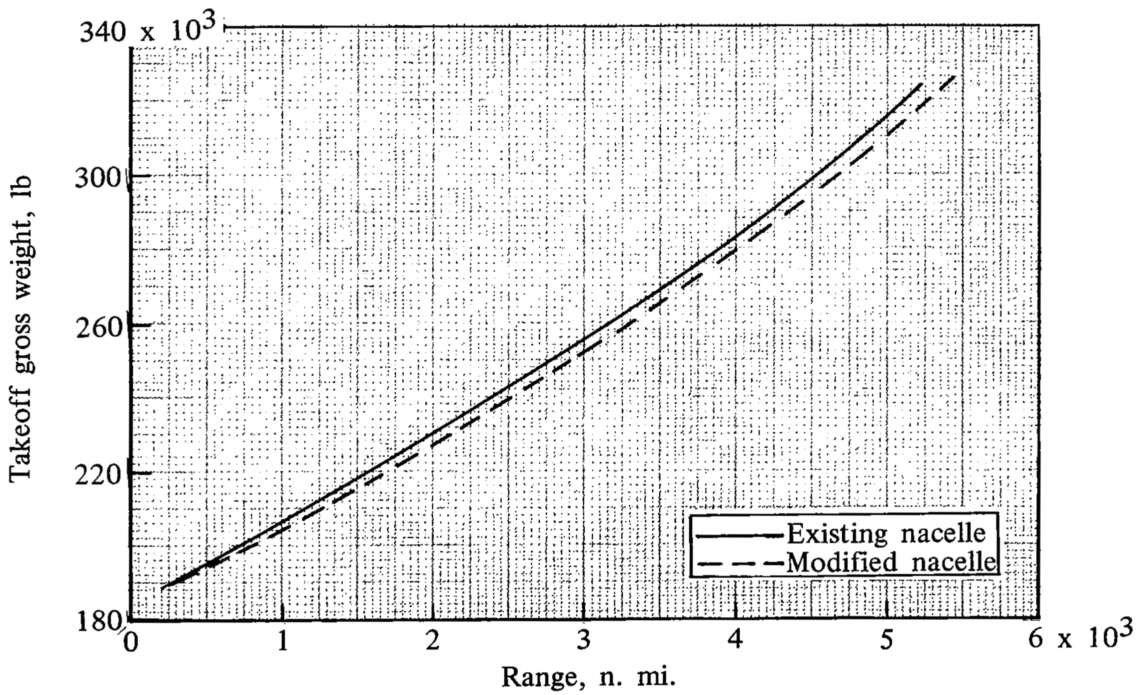


Figure 54. – Airplane gross weights at takeoff for domestic operating rules.

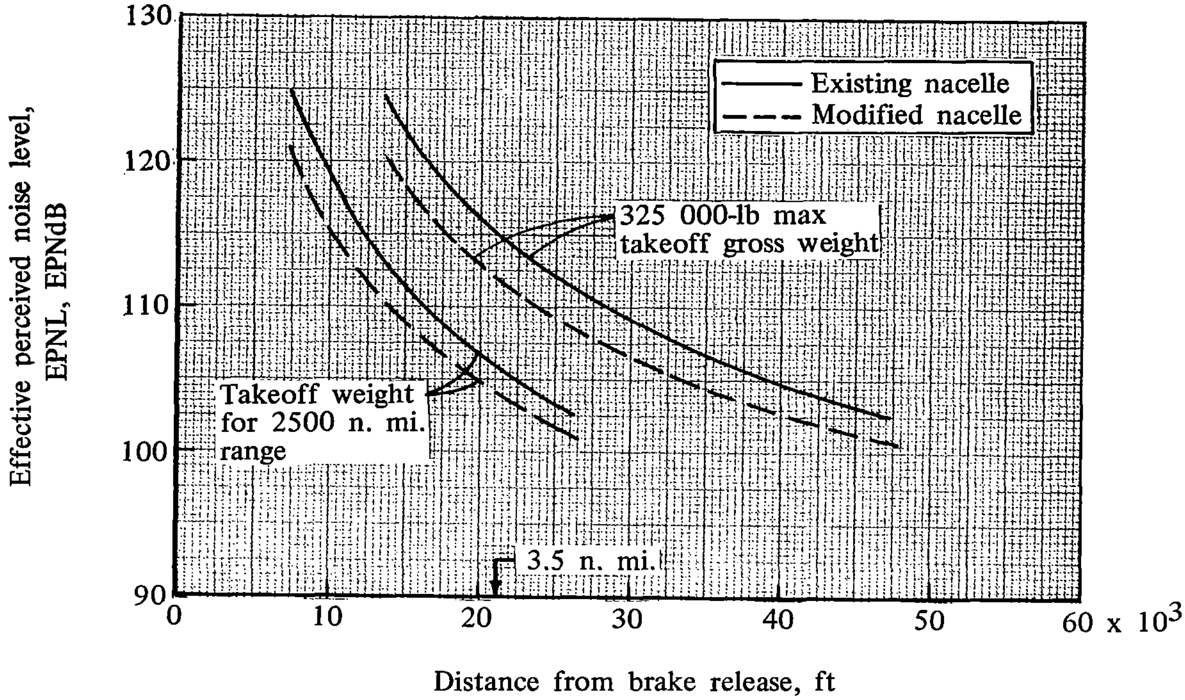


Figure 55. – EPNL under initial-climb flight paths.

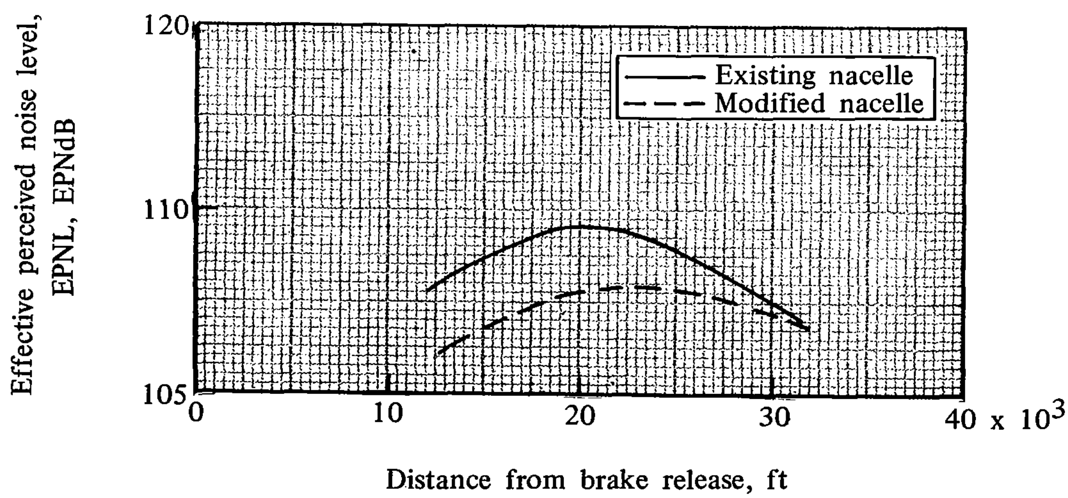


Figure 56. – EPNL along a line 1500 ft to the side of the initial-climb flight path for a DC-8-55 with 325 000-lb takeoff gross weight.

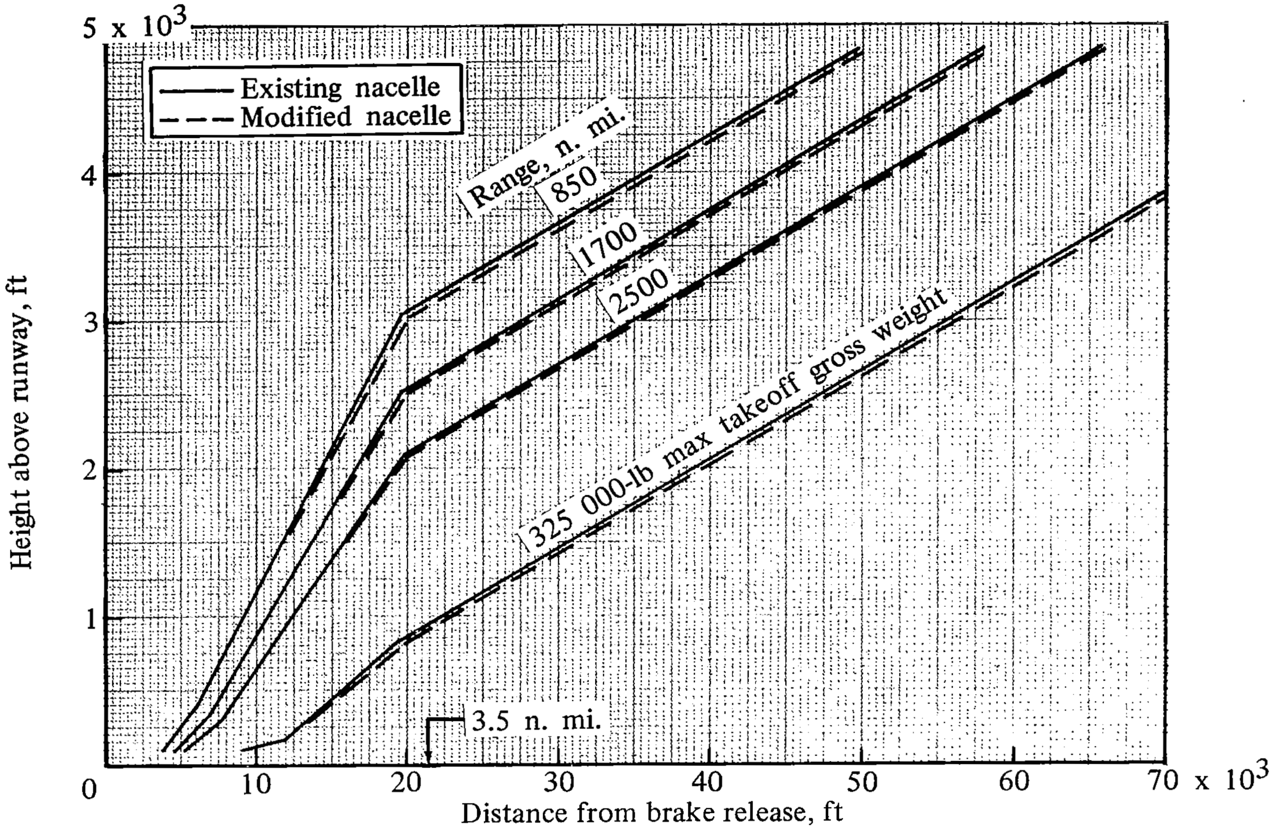


Figure 57. – Takeoff and reduced-thrust initial-climb flight paths for the DC-8-55 airplane; 6 percent climb gradient; V_2 + 10 kn climb airspeed; landing gear retracted; 25-degree flap setting.

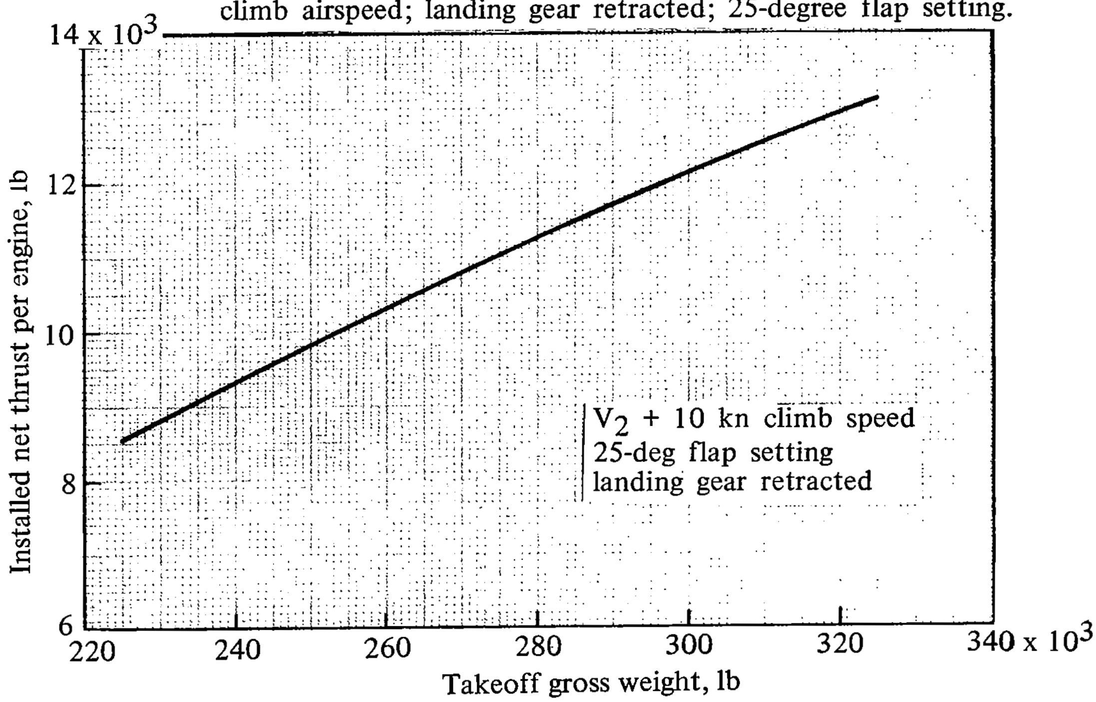
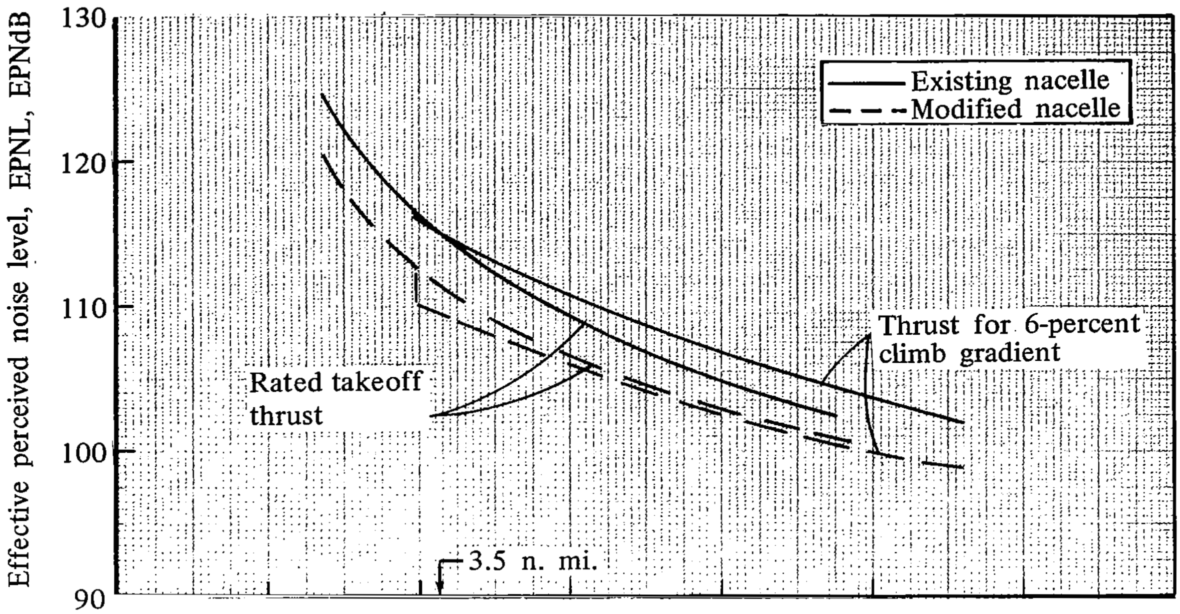
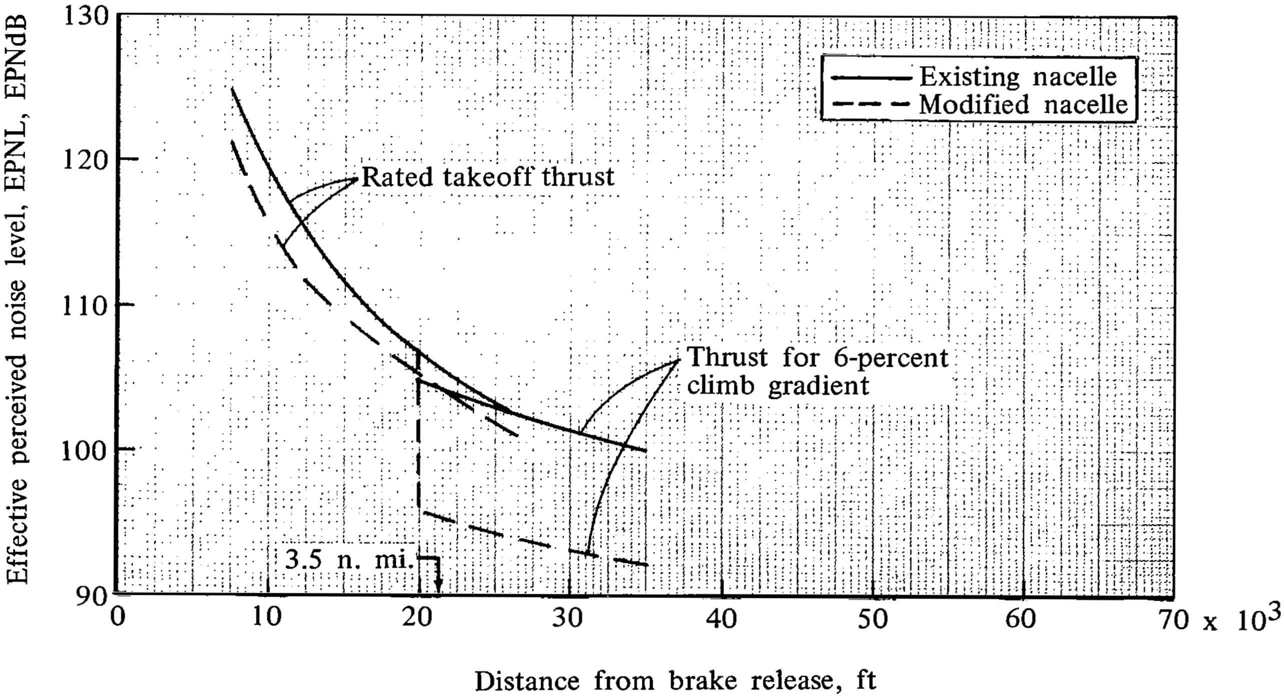


Figure 58. – Thrust required to maintain a 6-percent climb gradient for existing or modified airplanes.

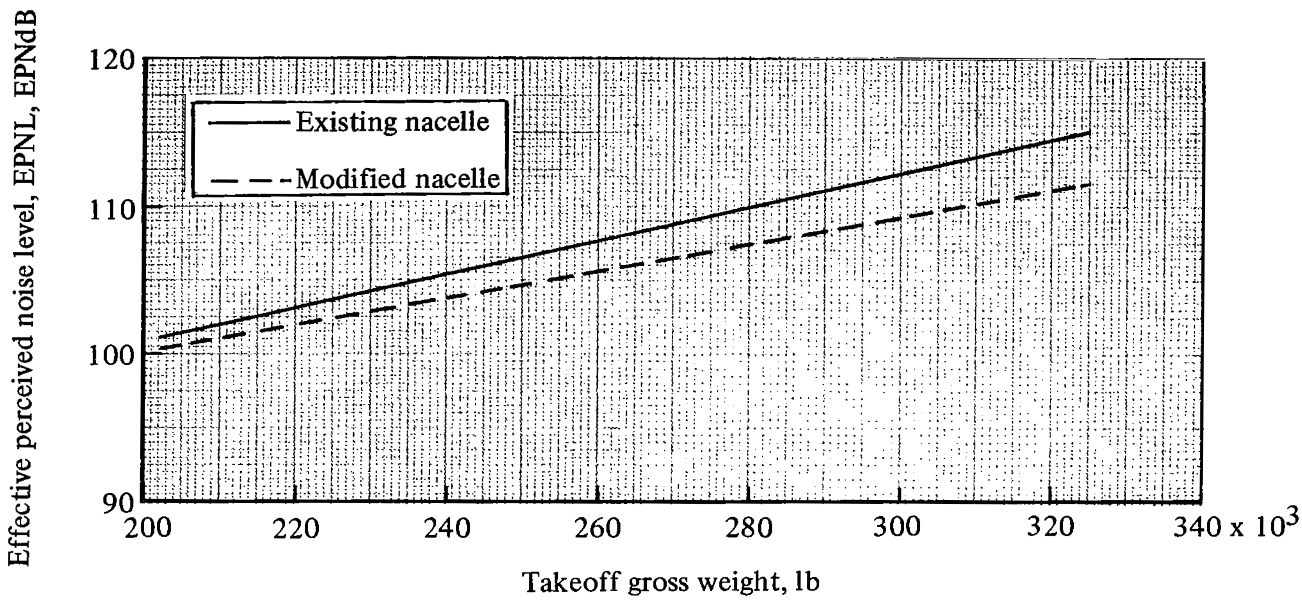


(a) 325 000-lb max takeoff gross weight.

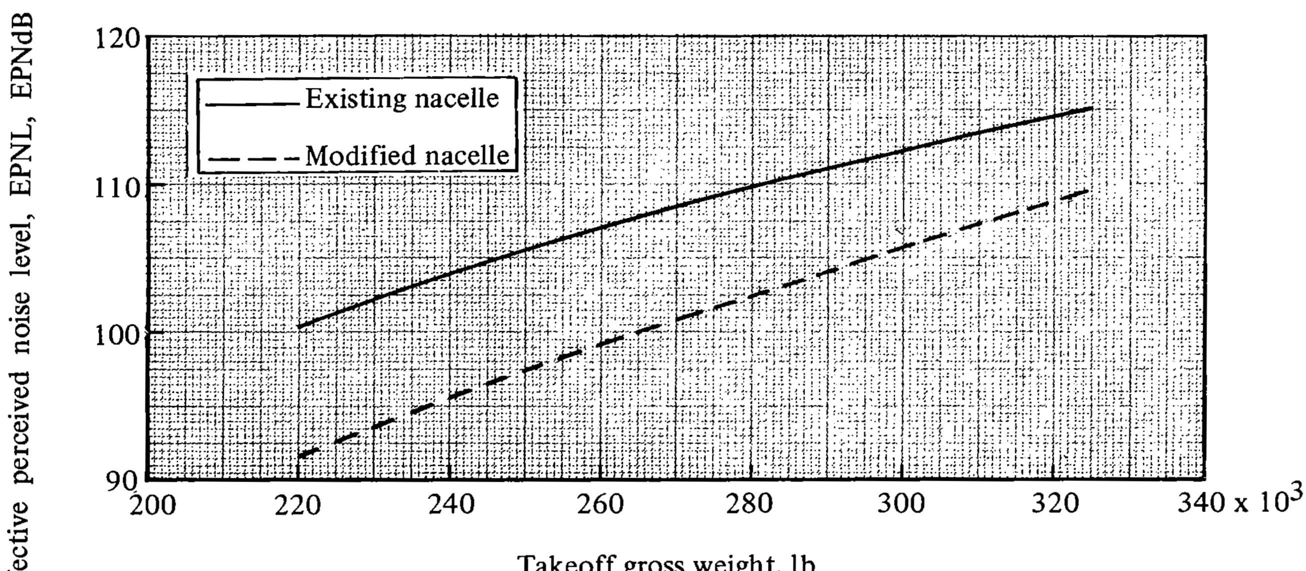


(b) Takeoff weight for 2500 n. mi. range.

Figure 59. – EPNLs under initial-climb flight paths; V_2 + 10 kn climb airspeed. (Takeoff-rated thrust maintained to 1500 feet before 3.5 n. mi. point, then reduced to that required for 6 percent climb gradient.)

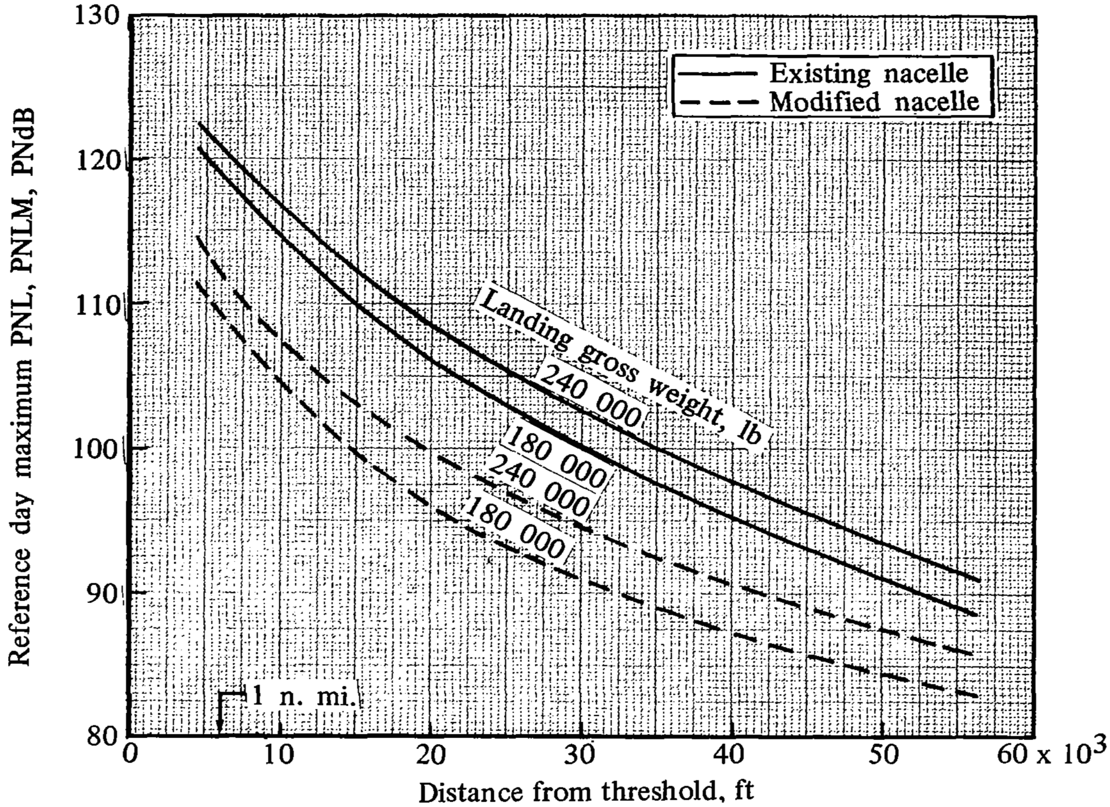


(a) Climb with takeoff-rated thrust.

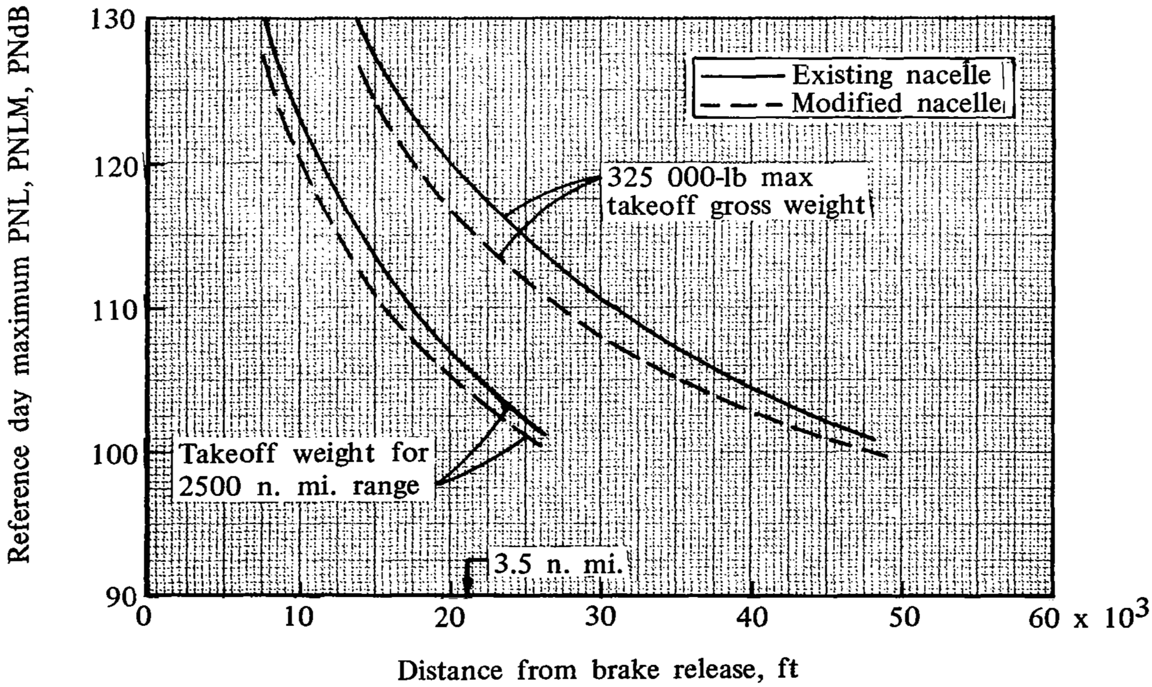


(b) Thrust for 6-% climb gradient.

Figure 60. – Variation of EPNL under initial-climb path at the 3.5-n. mi. point.

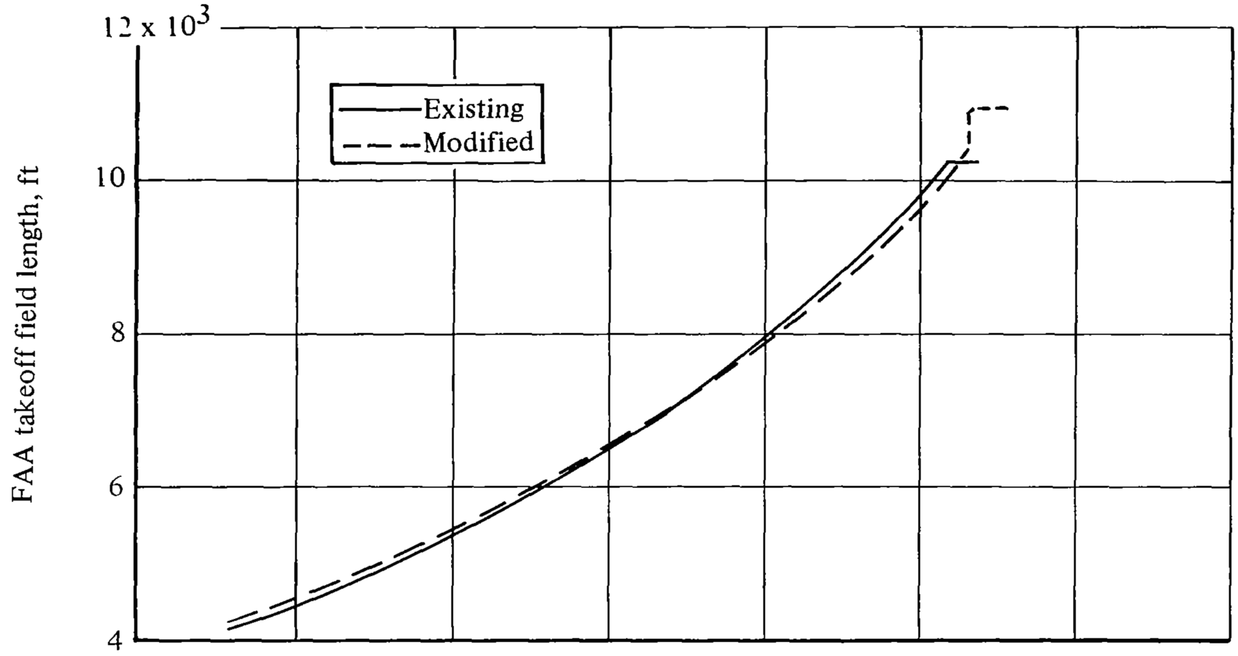


(a) 3-deg landing approach.

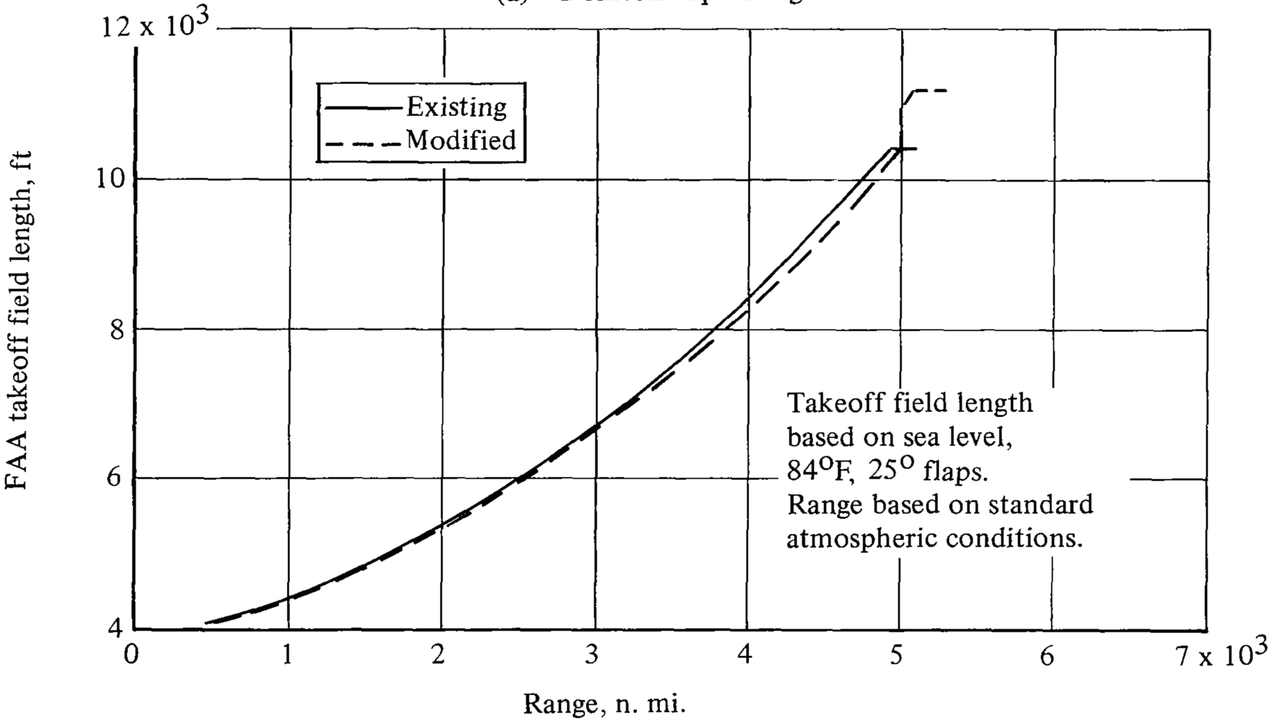


(b) Climb with takeoff-rated thrust; V_2 + 10 kn airspeed.

Figure 61. – PNLMs under flight path for reference atmospheric conditions of 59°F and 70 percent relative humidity.

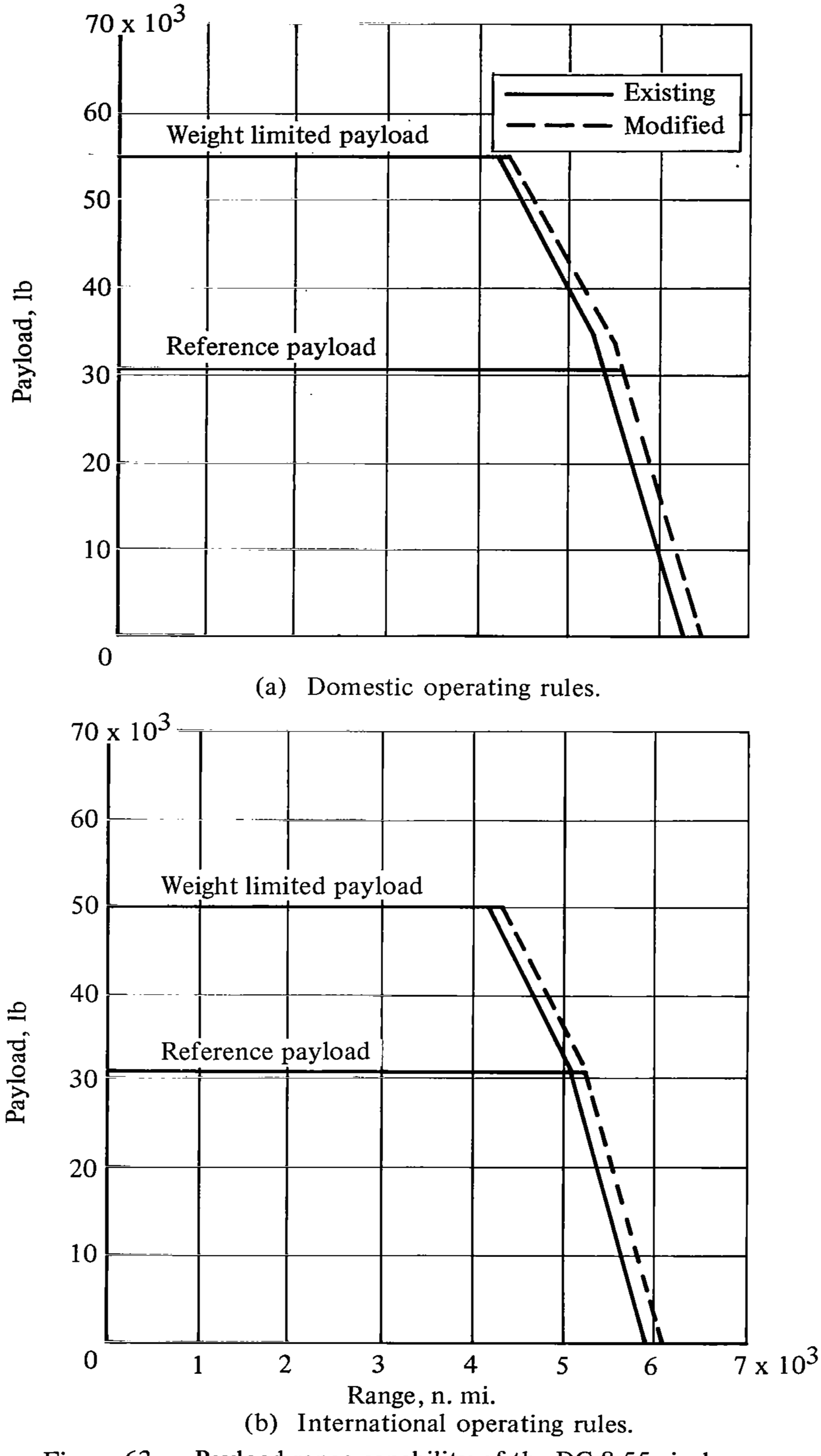


(a) Domestic operating rules.



(b) International operating rules.

Figure 62. – FAA-required takeoff field lengths with the reference payload.



(b) International operating rules.

Figure 63. – Payload-range capability of the DC-8-55 airplane.